TECHNICAL DOCUMENT TO SUPPORT WATER RESERVATIONS FOR THE KISSIMMEE RIVER AND CHAIN OF LAKES

Draft Report

~~April~~May 2020

South Florida Water Management District

West Palm Beach, FL

EXECUTIVE SUMMARY

This document summarizes the technical basis for developing the Kissimmee River and Chain of Lakes Water Reservations by the South Florida Water Management District to protect fish and wildlife. Protection of fish and wildlife means ensuring the health and sustainability of fish and wildlife communities through natural cycles of drought, flood, and population variation. The proposed Water Reservation area encompasses approximately 172,500 acres, including the following waterbodies: 1) Upper Chain of Lakes (Lakes Hart and Mary Jane; Lakes Myrtle, Preston and Joel; East Lake Tohopekaliga; Lake Tohopekaliga; the Alligator Chain of Lakes; and Lake Gentry), 2) Headwaters Revitalization Lakes (Lake Kissimmee, Cypress Lake, Lake Hatchineha, and Tiger Lake), and 3) the Kissimmee River and floodplain as well as interconnected canals.

The Water Reservations will reserve from allocation 1) all surface water in the Kissimmee River and floodplain and in the Headwaters Revitalization Lakes; 2) quantities of surface water up to established water reservation stages in the Upper Chain of Lakes; and 3) surface water and groundwater in the surficial aquifer system, within contributing waterbodies that is required for the protection of fish and wildlife.

The Headwaters Revitalization Lakes are closely associated with the performance of the Kissimmee River Restoration Project (KRRP) and have a separate federal regulation schedule intended to meet the flow requirements of the KRRP. The KRRP involves an estimated $800 million public investment and was developed to address public concerns about the effects of the Central and Southern Florida Flood Control Project on the Kissimmee River—specifically the altered hydrology, loss of floodplain wetlands, and resulting loss of habitat and reduced populations of many species of fish and wildlife. Federal authorizations for the KRRP form the basis for reserving all surface water in the Kissimmee River and floodplain and in the Headwaters Revitalization Lakes.

This document describes how the Water Reservations were developed. All Water Reservations are adopted by rule in the Florida Administrative Code. Once the draft Water Reservation rules are in effect, they will be implemented in the South Florida Water Management District's water use permitting program to ensure future water uses will not withdraw reserved water. Direct and indirect withdrawals of water from the Kissimmee River and floodplain and the Headwaters Revitalization Lakes will be limited to existing permitted water use allocations (existing legal uses). Direct and indirect withdrawals of water from the Upper Chain of Lakes and contributing waterbodies will be limited to existing permitted water use allocations (existing legal uses) and quantities of surface water up to the proposed Water Reservation stages given in the draft Water Reservation rules, as discussed in **Chapter 5** of this document. All existing legal uses of water from the reservation and contributing waterbodies will continue to be protected after rule adoption if they are not contrary to the public interest.

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASUREMENT

2008 LORS	2008 Lake Okeechobee Regulation Schedule
AFET-W	Alternative Formulation and Evaluation Tool – Water Reservation
Applicant's Handbook	*Applicant's Handbook for Water Use Permit Applications in the South Florida Water Management District*
C&SF Project	Central and Southern Florida Flood Control Project
CERP	Comprehensive Everglades Restoration Plan
cfs	cubic feet per second
cm	centimeter
cm/s	centimeters per second
District	South Florida Water Management District
F.S.	Florida Statutes
FAS	Floridan aquifer system
ft	foot
ft/s	feet per second
FWC	Florida Fish and Wildlife Conservation Commission
HRS	Headwaters Revitalization Schedule
KCOL	Kissimmee Chain of Lakes
km	kilometer
KRRP	Kissimmee River Restoration Project
LKB	Lower Kissimmee Basin
LOSA	Lake Okeechobee Service Area
m	meter
MFL	Minimum Flow and Minimum Water Level
NGVD29	National Geodetic Vertical Datum of 1929
RAA	Restricted Allocation Area
SAS	surficial aquifer system
SFWMD	South Florida Water Management District
UCOL	Upper Chain of Lakes
UK-OPS	Upper Kissimmee – Operations Simulation (Model)
UKB	Upper Kissimmee Basin
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
WRL	water reservation line

CHAPTER 1: INTRODUCTION

1.1 Overview and Purpose of Document

This document summarizes the technical and scientific data, assumptions, models, and methodology used to support rule development to reserve water for the protection of fish and wildlife for specific waterbodies located in the Kissimmee River and Chain of Lakes. The meaning of "water needed to protect fish and wildlife" (i.e., ensuring the health and sustainability of fish and wildlife communities through natural cycles of drought, flood, and population variation) is discussed in more detail in **Chapter 2**. A Water Reservation is a legal mechanism to set aside water from consumptive use for the protection of fish and wildlife or for public health and safety. A Water Reservation may be established in such locations and quantities, and for such seasons of the year, as may be required for the protection of fish and wildlife or for public health and safety.

The waterbodies included in the proposed Kissimmee River and Chain of Lakes Water Reservations (Water Reservations) are components of the Central and Southern Florida Flood Control Project (C&SF Project). The C&SF Project is a multi-objective project, originally authorized by the Flood Control Act of 1948 and modified by subsequent acts, that provides for flood control, drainage, water supply, and other purposes. The South Florida Water Management District (SFWMD or District) is the local sponsor of the C&SF Project [Section 373.1501, Florida Statutes (F.S.)]. In 1992, the United States Congress authorized the C&SF Project to include ecosystem restoration of the Kissimmee River and improvement of habitat in the Kissimmee River Headwaters Lakes. In its capacity as local sponsor, the SFWMD operates and maintains the C&SF Project, including the subject reservation waterbodies. Operation of project components is required to occur in accordance with federally adopted regulation schedules and water management to meet project goals. The regulation schedules define maximum lake stages and water releases from the waterbodies and are specifically related to stage and time of year. Therefore, the proposed Water Reservations must dovetail with the authorized federal regulation schedules for the subject waterbodies.

1.2 Reservation Waterbodies

The reservation waterbodies are listed below and shown in **Figure 1-1**, and include contributing waterbodies or tributaries, as described in other chapters of this document.

1. Upper Chain of Lakes (UCOL) – six lake groups
    a. Lakes Hart-Mary Jane
    b. Lakes Myrtle-Preston-Joel
    c. Alligator Chain of Lakes
    d. Lake Gentry
    e. East Lake Tohopekaliga
    f. Lake Tohopekaliga
2. Headwaters Revitalization Lakes – one lake group
    a. Lakes Kissimmee-Cypress-Hatchineha-Tiger
3. Kissimmee River and floodplain

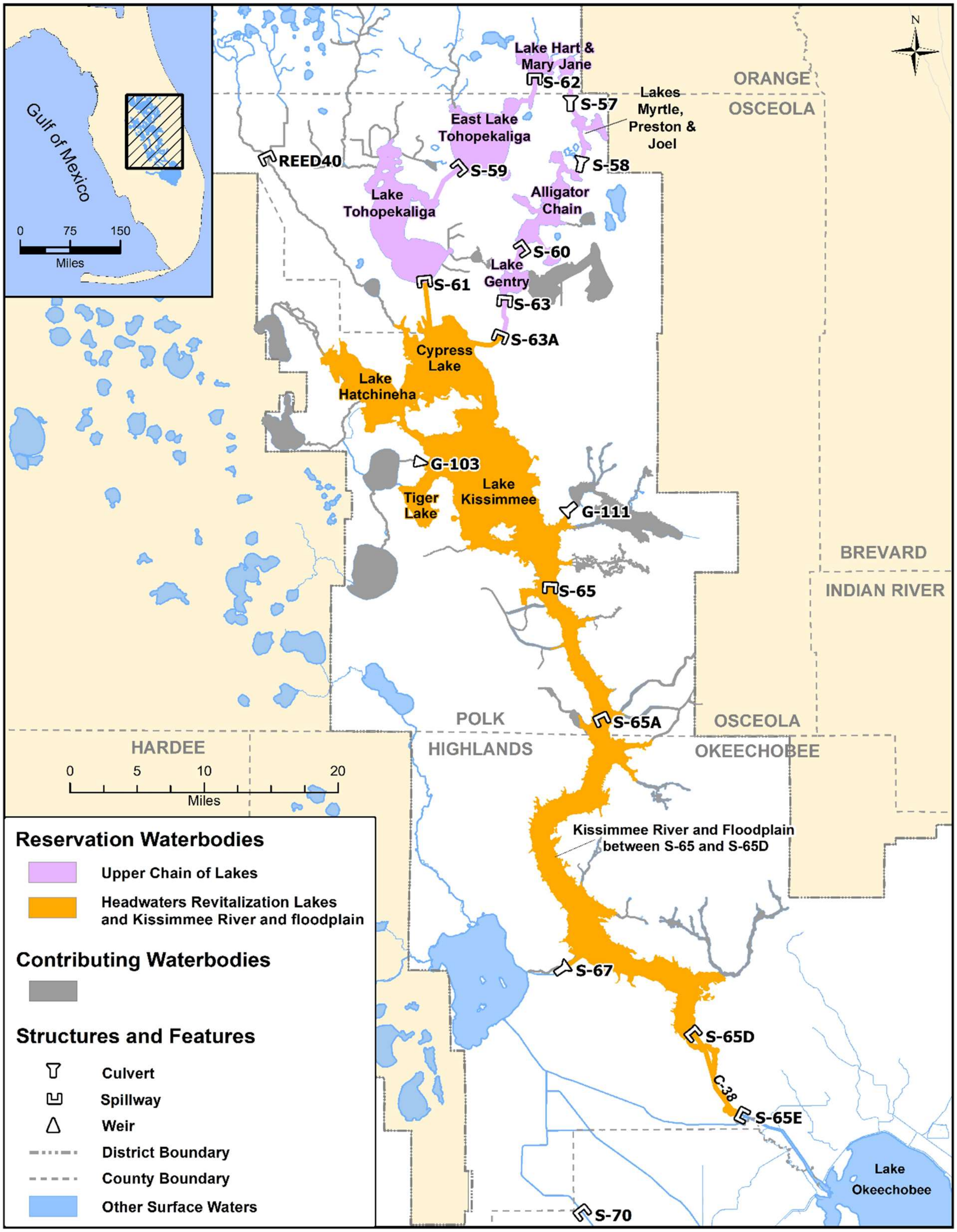


Figure 1-1. Kissimmee River and Chain of Lakes Water Reservation waterbodies.

The Kissimmee River reservation waterbodies include the Kissimmee River and its 100-year floodplain, as delineated by the United States Army Corps of Engineers (USACE), between the S-65 and S-65D structures; the Istokpoga Canal and floodplain east of the S-67 structure; and the C-38 Canal and remnant river channels from the S-65D to S-65E structures (**Figure 1-1**). It also includes restored sections of the Kissimmee River from the S-65 structure to Lake Okeechobee.

The remaining reservation waterbodies consist of one or more lakes and interconnecting canals in the Headwaters Revitalization Lakes and UCOL. These two groups of lakes, which contain several reservation waterbodies, are collectively referred to as the Kissimmee Chain of Lakes (KCOL). All waterbodies in these sections are part of the C&SF Project or are hydrologically connected to the C&SF Project by man-made or natural conveyance features, and they contribute flows to each other as well as to the Kissimmee River. These reservation waterbodies are managed in accordance with water control structure regulations and schedules prescribed by the USACE (1994), which are significant constraints that were considered in the quantification of water needed for protection of fish and wildlife. The reservation waterbodies and contributing waterbodies are described in more detail in **Chapter 3** and **Appendix A**. The water needed for the protection of fish and wildlife and proposed for reservation is described in **Chapter 5** and **Appendix B**.

In addition to their natural values, the reservation waterbodies are significant because, as part of a diverse group of wetland, lake, and river/floodplain ecosystems, they form a substantial portion of the headwaters of the Kissimmee-Okeechobee-Everglades system. SFWMD and other state and federal agencies have invested considerable resources in managing waterbodies in this region of Florida. The most noteworthy investment is the Kissimmee River Restoration Project (KRRP). The meandering Kissimmee River was channelized between 1962 and 1971, resulting in severe damage to the biological communities of the river and floodplain, which prompted immediate calls for restoration. The steps taken toward restoration of the Kissimmee River are summarized in **Section 1.3**.

1.3 Kissimmee River and Chain of Lakes Background

This section provides background information regarding events that helped form the need and basis for the Kissimmee River and Chain of Lakes Water Reservations. The long-term commitment of the federal government, State of Florida, and SFWMD to restore the Kissimmee River and floodplain under the KRRP is the genesis of many supporting activities. **Table 1-1** provides a brief chronology of major actions and events associated with the KRRP.

Table 1-1. Major actions and events in the planning, development, and implementation of the Kissimmee River Restoration Project.

Time Period	Major Action or Event
1920s-1940s	Hurricanes and flooding in the Upper Kissimmee Basin
1954	United States Congress authorizes the Kissimmee portion of the C&SF Project
1962-1971	C&SF Project channelizes the Kissimmee River
1971	Governor's Conference on Water Management recommends restoration of the Kissimmee River
1976	Kissimmee River Restoration Act [Chapter 76-113, F.S.] creates the Kissimmee River Coordinating Council
1978-1985	First federal feasibility study notes potential for restoration, but federal funding not feasible (USACE 1985)
1983	Kissimmee River Coordinating Council recommends the backfilling plan
1984-1990	Kissimmee River Demonstration Project shows restoration is possible

Time Period	Major Action or Event
1986	The Water Resources Act mandates that enhancements to environmental quality in the public interest should be calculated as equal to other costs
1988	Kissimmee River Restoration Symposium adopts the ecological integrity goal
1991	Second federal feasibility study recommends the Level II backfilling plan (USACE 1991)
1992	The Water Resources Development Act authorizes the Kissimmee River Restoration Project
1994	The Department of the Army and SFWMD (1994) sign a project cooperative agreement
1994	Construct test backfill and conduct high-flow tests on backfill stability
1996	Headwaters Revitalization Feasibility Study completed (USACE 1996)
1995-1999	SFWMD conducts baseline sampling for Phase I construction (Bousquin et al. 2005a)
1999-2001	Phase I backfilling completed, and monitoring continues (Bousquin et al. 2005a)
2006-2009	Phases IVA and IVB backfilling completed and monitoring continues
2014	Publication of nine manuscripts in *Restoration Ecology* on interim ecosystem response to restoration in the Phase I area (Anderson 2014a,b, Bousquin and Colee 2014, Cheek et al. 2014, Colangelo 2014, Jordon and Arrington 2014, Koebel and Bousquin 2014, Koebel et al. 2014, Spencer and Bousquin 2014)
2015-2020	Phase II/III backfilling and S-69 weir to be completed
2020	Expected implementation of Final Headwaters Revitalization Schedule following completion of all project construction and land acquisition
2020-2025	SFWMD to conduct post-construction monitoring and evaluation for Phases I and II/III construction areas

C&SF Project = Central and Southern Florida Flood Control Project; F.S. = Florida Statutes; SFWMD = South Florida Water Management District; USACE = United States Army Corps of Engineers.

1.3.1 Kissimmee River Restoration

Before the Kissimmee River was channelized, it meandered for 103 miles between Lakes Kissimmee and Okeechobee (Koebel 1995). The river channel provided diverse habitats associated with sand bars and narrow vegetation beds as well as variable flow conditions depending on inflow and channel morphology (Toth et al. 1995). The river frequently overflowed its banks and inundated the 1- to 2-mile wide floodplain for extended periods of time, maintaining a mosaic of wetland plant communities. After the river was channelized by the construction of the C-38 flood control canal, most of the floodplain was drained and the remaining portions of the historical river channel no longer received flow. Because the canal conveyed all flow from the lakes to the north as well as local runoff, overbank flooding was virtually eliminated, ending significant inundation of the river's floodplain. As a result of these changes, habitat in the river channel and floodplain declined dramatically, with concomitant effects on native fish and wildlife.

Reconstruction of the Kissimmee River has been occurring in phases since 1999. Three of five construction phases are complete. Since completion of the first phase of construction, pre-channelization hydrologic conditions have been partially re-established (Bousquin et al. 2007, 2009), and partial recoveries have been documented in fish, wildlife, and plant communities. **Figure 1-2** shows the portion of the Kissimmee River that is being restored. Further improvement is expected after the new USACE Headwaters Revitalization Schedule (HRS), described in **Chapter 4**, is implemented at the S-65 water control structure, which controls discharge to the Kissimmee River. Until all phases of construction are complete, an interim regulation schedule is in place that does not provide the full benefits of the HRS. However, fish, wildlife, and habitat responses within project areas are being monitored using river/floodplain restoration performance measures under the SFWMD's Kissimmee River Restoration Evaluation Program. An integral component of the restoration is the reservation from allocation of water needed for protection of fish and wildlife. The water identified for the natural system will be protected through a Water Reservation, as authorized by Florida law.

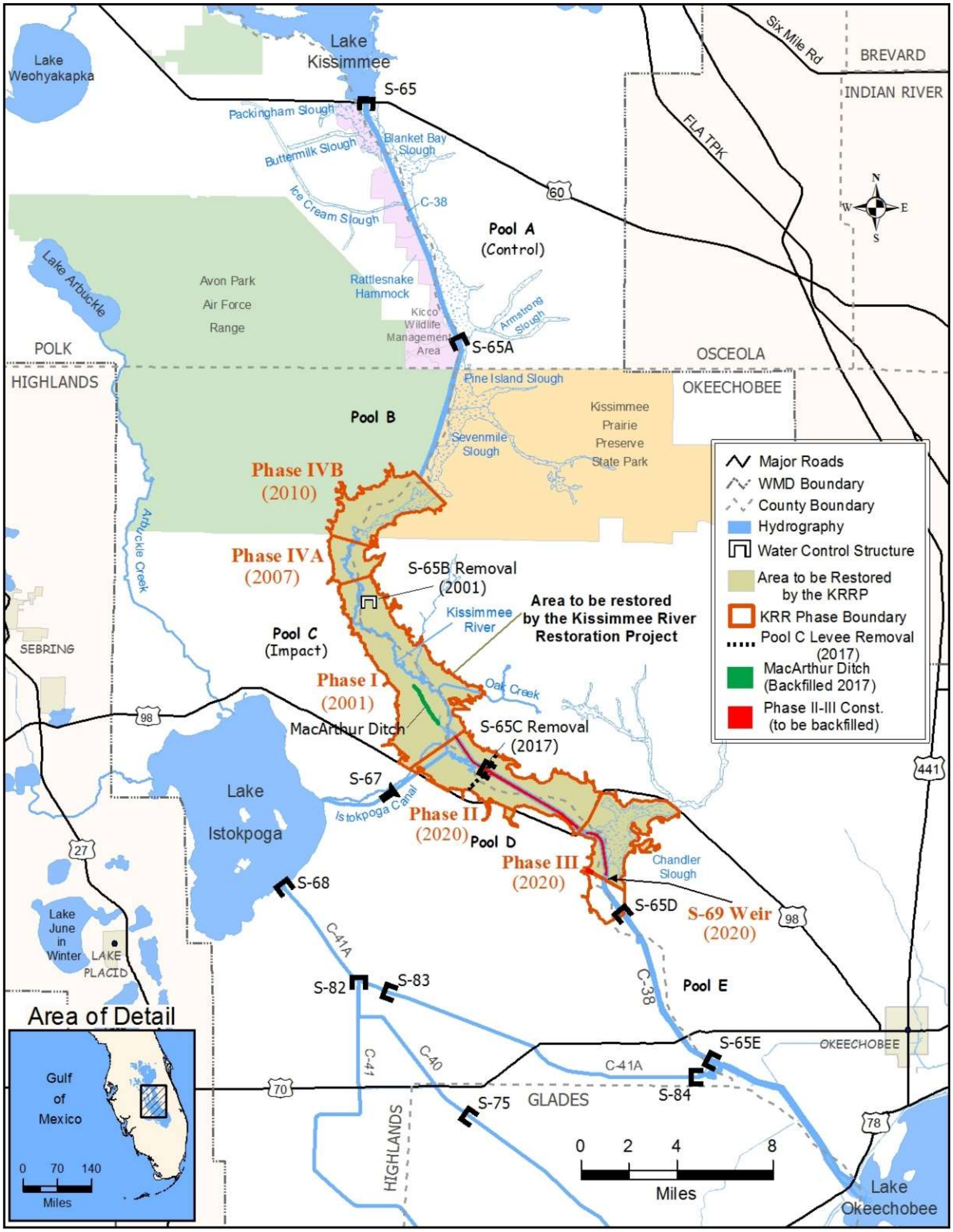


Figure 1-2. Map of the area being restored by the Kissimmee River Restoration Project.

1.3.2 Headwaters Revitalization Project

A key element of planning for the KRRP was development of a new regulation schedule for the S-65 structure (i.e., the HRS). The HRS was developed to provide the water storage and hydrology necessary to meet the ecological integrity goal of the KRRP (Koebel and Bousquin 2014). The HRS was authorized by Congress in 1992. In November 1996, the USACE issued its record of decision approving the recommended plan described in USACE (1996), including the construction plan and the new regulation schedule, finding it "to be economically justified, in accordance with environmental statutes, and in the public interest."

1.3.3 Central Florida Water Initiative

In 2006, the Central Florida Coordination Area "Action Plan" was initiated among three water management districts—St. Johns River Water Management District, Southwest Florida Water Management District, and SFWMD—to address short- and long-term development of water supplies in the Central Florida area, specifically Orange, Osceola, Seminole, Polk, and southern Lake counties. This effort evolved into the ongoing Central Florida Water Initiative, a collaborative effort among the aforementioned water management districts, other government agencies, and various stakeholders to address current and long-term water supply needs in a five-county area in the Central Florida region. In November 2015, the Governing Boards of the three water management districts approved the 2015 Central Florida Water Initiative Regional Water Supply Plan (Central Florida Water Initiative 2015), including the 2035 Water Resources Protection and Water Supply Strategies Plan.

At the time of this writing, the draft 2020 Central Florida Water Initiative Regional Water Supply Plan is undergoing public review and comment. Governing boards of the three water management districts are anticipated to approve the plan in November 2020. The draft plan recognizes the SFWMD is developing the Kissimmee River and Chain of Lakes Water Reservations to protect the volume of water needed for fish and wildlife in the Kissimmee River restored conditions. The increased demands projected through 2040 in the draft plan can be met through development of alternative water supplies and other management strategies. Potential project options do not include surface water from the Kissimmee River and Chain of Lakes.

1.4 Prior Work on the Kissimmee River and Chain of Lakes Water Reservations

In June 2008, SFWMD's Governing Board initiated rule development for the Kissimmee River and Chain of Lakes's Water Reservation. The technical information presented here identifies the hydrologic requirements to ensure protection of fish and wildlife and forms the basis for the current rule development process.

In March 2009, SFWMD (2009) developed a draft technical document to support Water Reservation rule development efforts. The document was evaluated by an independent, scientific peer-review panel in April 2009, in accordance with Florida Department of Environmental Protection guidance in Rule 62-40.474(4), Florida Administrative Code. The 2009 peer-review panel was asked to assess the scientific and technical data, methodologies, models, and assumptions employed in each model, as summarized in the 2009 draft technical document, and evaluate their validity and soundness. The peer-review panel found the supporting data and information used were technically sound, including the inferences and assumptions made regarding the linkages between hydrology and the protection of fish and wildlife (Aday et al. 2009).

The initial Water Reservation development effort was suspended due to ongoing work that, at the time, had the potential to change the regulation schedules within the UCOL. In June 2014, SFWMD's Governing Board reinitiated the Water Reservation rule development effort. A public rule development workshop was held on July 30, 2014. On December 12, 2014, draft Water Reservation rules were presented during a rule development workshop. In March 2015, a draft technical document was developed (SFWMD 2015a), and public comments on the draft were solicited. Rule development efforts were suspended again in 2016 to address concerns related to threatened and endangered species. Work on the Water Reservations began again in 2018, and the technical document was updated to its present form. Once adopted, the Water Reservation rule criteria will be implemented in the SFWMD's water use permitting program and will require applicants to provide reasonable assurance that their proposed use of water will not withdraw water reserved for the protection of fish and wildlife in the Kissimmee River and Chain of Lakes.

SFWMD's technical approach to quantify water needed for the protection of fish and wildlife in the Kissimmee River and Chain of Lakes is outlined in **Chapters 3** through **5** and involves several steps, including identification of the following:

1. Water reservation waterbodies;
2. Habitat and fish and wildlife species to be protected;
3. Hydrologic links to habitat, fish, and wildlife; and
4. Water volumes to be reserved.

CHAPTER 2: BASIS FOR WATER RESERVATIONS

2.1 Definition and Statutory Authority

A Water Reservation is a legal mechanism to reserve a quantity of water from consumptive use for the protection of fish and wildlife or for public health and safety.

Section 373.223(4), F.S., states the following:

> *The governing board or the department, by regulation, may reserve from use by permit applicants, water in such locations and quantities, and for such seasons of the year, as in its judgment may be required for the protection of fish and wildlife or the public health and safety. Such reservations shall be subject to periodic review and revision in the light of changed conditions. However, all presently existing legal uses of water shall be protected so long as such use is not contrary to the public interest.*

It is reasonable to interpret "protection" to mean ensuring the health and sustainability of fish and wildlife communities through natural cycles of drought, flood, and population variation. *See* Fla. Div. of Admin. Hr'gs (2006) Case 04-000880RP. When water is reserved pursuant to Section 373.223(4), F.S., it is unavailable for allocation to new or increased consumptive uses. However, existing legal uses of water are protected so long as such uses are not contrary to the public interest. An existing legal use is a water use that is authorized in a water use permit pursuant to Part II of Chapter 373, F.S., or is exempt from water use permit requirements.

It is equally important to understand the limitations of water reservations. Water reservations do not drought-proof a natural system, ensure wildlife proliferation, or establish an operating regime. While Part II, Chapter 373, F.S., authorizes SFWMD to permit consumptive uses and establish water reservations, it does not authorize SFWMD to establish operating criteria for the C&SF Project system or for Comprehensive Everglades Restoration Plan (CERP) projects. C&SF Project system and CERP project operating criteria are established by USACE and implemented by SFWMD through federal and state authorities. However, the project operating criteria affect the timing and availability of water in the District; therefore, the operating plans must be consistent with established Water Reservation and permitted water allocations.

The Florida Legislature gave broad discretion to the Governing Boards of Florida's five water management districts to exercise judgment in establishing water reservation, taking into consideration the water needs of fish and wildlife as well as public health and safety while also balancing the overall district missions. Districts are directed to periodically review and revise adopted water reservations, as needed, to achieve this balance.

The SFWMD elected to use its Water Reservation authority conferred by Section 373.223(4), F.S., to reserve quantities of water in the Kissimmee River and Chain of Lakes for the protection of fish and wildlife. The draft Water Reservation rules also support the restoration goals and objectives of the KRRP. The rulemaking is based on the technical information and recommendations in this document.

2.2 Water Reservation Rulemaking Process

The general process of Water Reservation rulemaking includes several steps (**Figure 2-1**). The Kissimmee River and Chain of Lakes Water Reservations rule development originally was authorized by the SFWMD Governing Board in June 2008. Analyses and a supporting technical document were completed and peer reviewed in 2009. The project was subsequently postponed in 2009, but SFWMD's Governing Board authorized re-initiation of the project on June 12, 2014. A new Notice of Rule Development was published in the Florida Administrative Register on July 16, 2014. Building on the initial technical analysis conducted in 2008-2009, new and updated analyses and modeling were completed, and an updated technical document and Water Reservation rules were drafted between 2014 and 2016. Public workshops and key stakeholder meetings were held on July 30, 2014, December 12, 2014, January 08, 2015 (Water Resource Advisory Commission meeting), January 06, 2016, March 15, 2016, March 30, 2016, and April 08, 2016, to gain public input on the rulemaking process.

Since 2016, the Upper Kissimmee – Operations Simulation (UK-OPS) Model was completed for application to the rulemaking process, and revision of the draft Water Reservation rules, applicable sections of the *Applicant's Handbook for Water Use Permit Applications in the South Florida Water Management District* (Applicant's Handbook; SFWMD 2015b), and the revised technical document were completed. The detailed model documentation report for the UK-OPS Model is included as **Appendix C**. An independent, scientific peer review of the UK-OPS Model (**Appendix D**) was completed in November 2019. For more information regarding the 2009 peer review please see **Appendix E**.

Once consensus is reached and the draft Water Reservation rules are finalized, they will be presented to the SFWMD Governing Board for adoption. The SFWMD encourages stakeholder review and comment on the draft Water Reservation rules. There will be opportunities in future rule development workshops for stakeholders to give feedback prior to final rule adoption.

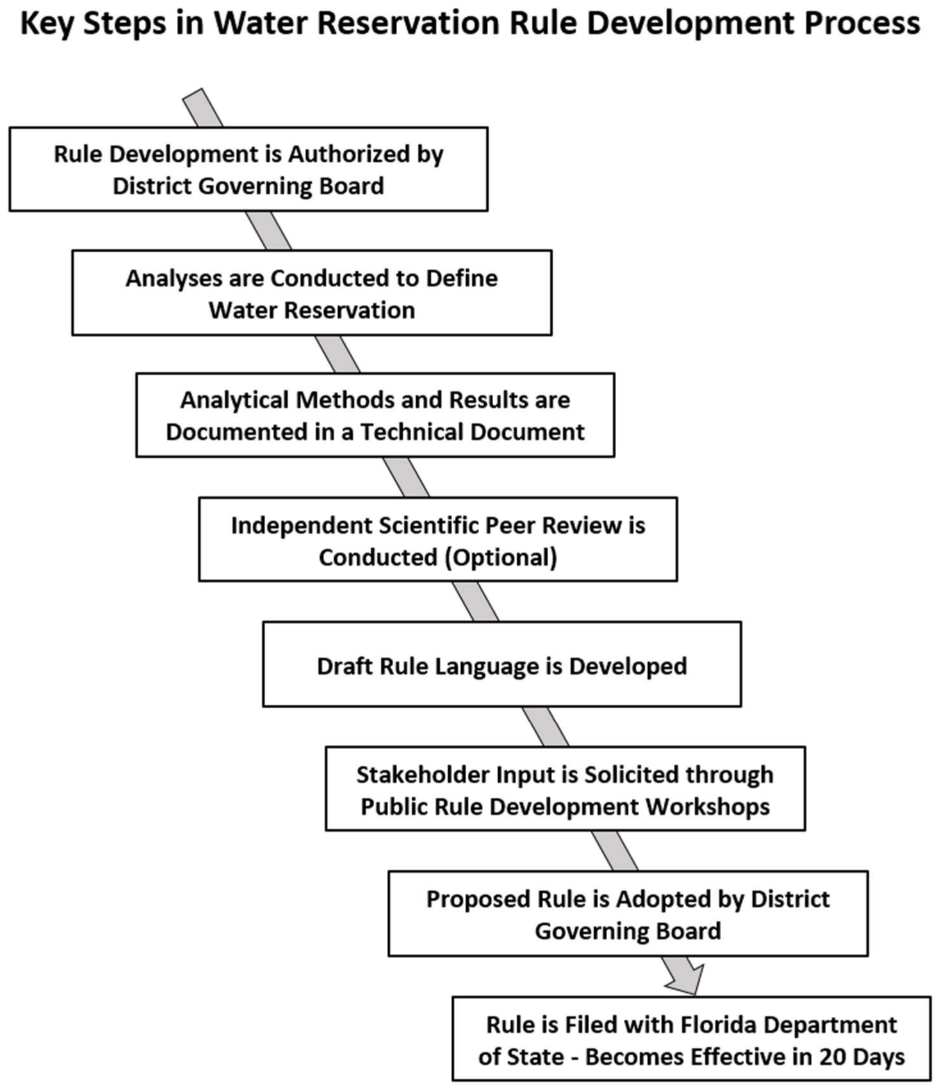


Figure 2-1. Water Reservation rule development process.

CHAPTER 3: DESCRIPTION OF RESERVATION WATERBODIES

3.1 Kissimmee Basin Overview

Located in Central Florida, the Kissimmee Basin encompasses the SFWMD's Upper Kissimmee Basin (UKB) and Lower Kissimmee Basin (LKB) water supply planning areas (**Figure 3-1**). The Kissimmee Basin is bounded to the north and east by the St. Johns River Water Management District, to the west by the Southwest Florida Water Management District, and to the south by Lake Okeechobee. Within its boundary are all or portions of six counties—Orange, Osceola, Polk, Highlands, Okeechobee, and Glades.

The Kissimmee Basin experiences a humid, subtropical climate with wet and dry seasons of nearly equal length. Average yearly rainfall is 48 inches (121 centimeters [cm]) in the UKB and 45 to 50 inches (114 to 127 cm) in the LKB. Most precipitation falls during a distinct wet season (June to October). Air temperature ranges from 41 to 86 degrees Fahrenheit (5 to 30 degrees Celsius).

The major physiographic features of the Kissimmee Basin were formed when much of Florida was submerged (White 1970). The Kissimmee Basin has a roughly north-northwest to south-southeast alignment that parallels relict sandy beach ridges created by longshore currents (Warne et al. 2000). Most of the basin lies within the Osceola Plain, which is 40 miles wide and 100 miles long. The Osceola Plain is bounded to the west by the Lake Wales Ridge and to the northwest by the Mount Dora and Orlando ridges (White 1970). A scarp separates the Osceola Plain from the Eastern Valley on the northeastern and eastern borders and from the Okeechobee Plain to the south. The highest elevation of the Osceola Plain occurs in the northwest corner, where it rises to 90 to 95 feet (ft) National Geodetic Vertical Datum of 1929 (NGVD29). However, most of the plain occurs between 60 and 70 ft NGVD29.

The remainder of the Kissimmee Basin lies on the Okeechobee Plain, which is 30 miles wide and 30 miles long. From the toe of the scarp separating it from the Osceola Plain, the elevation of the Okeechobee Plain decreases from 40 to 20 ft NGVD29 at the northern shore of Lake Okeechobee.

The sandy soils found throughout the Kissimmee Basin are derived primarily from marine-deposited silica sands. Most soil types in the UKB and LKB are classified under the Smyrna-Myakka-Basinger Soil Association. Additional information may be found in the Geotechnical Investigations Appendix of the *Central and Southern Florida Final Integrated Feasibility Report and Environmental Impact Statement Environmental Restoration Kissimmee River, Florida* (USACE 1991).

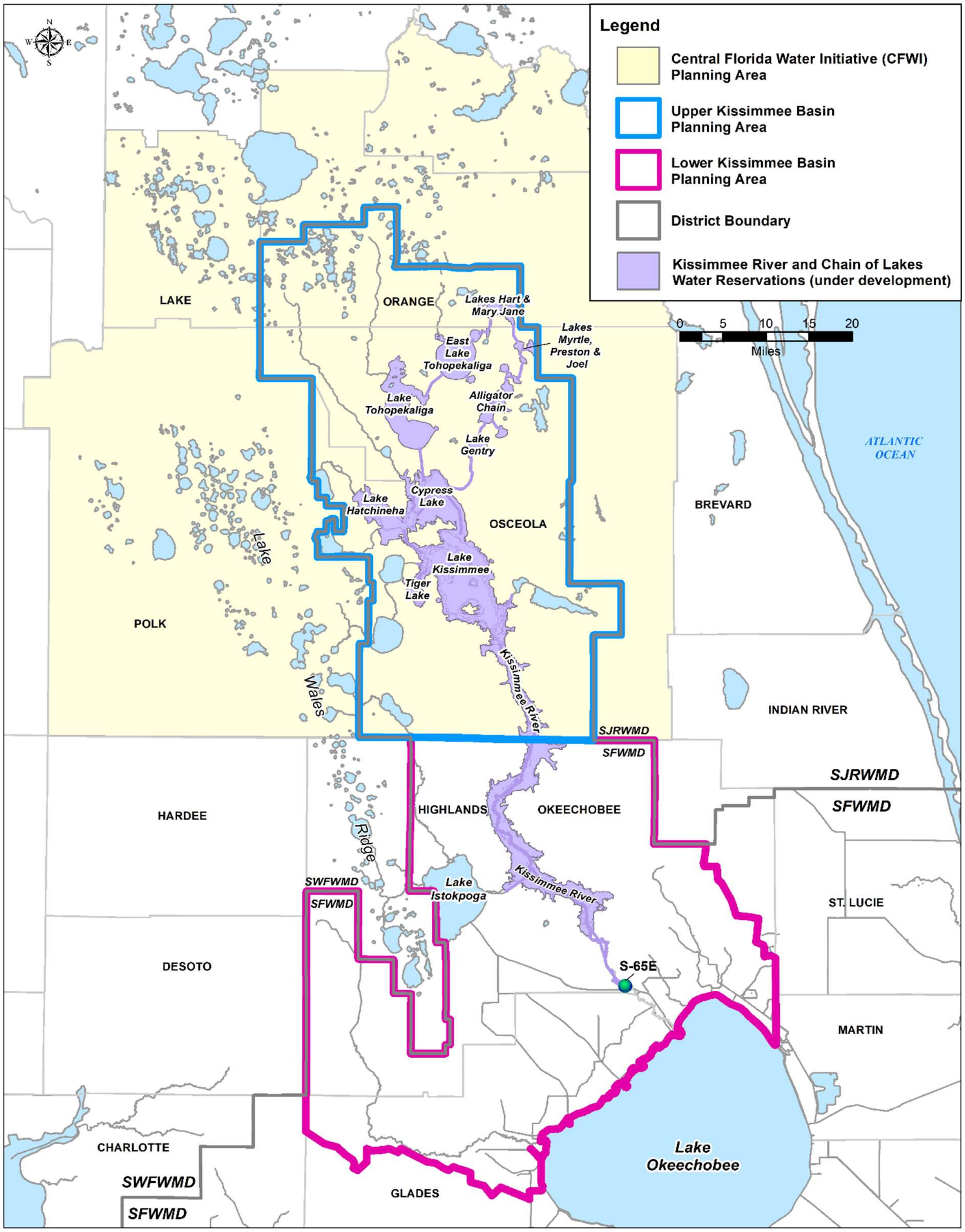


Figure 3-1. Map of the Upper and Lower Kissimmee Basins.

3.2 Surface Water Resources

The UKB has been incorporated into the Central Florida Water Initiative planning area (**Section 1.3.3**) and extends south to the Polk and Osceola county line (**Figure 3-1**). The UKB is 1,607 square miles (4,162 square kilometers [km^2]), more than twice the area of the LKB. The UKB contains hundreds of lakes and wetlands, with the largest lakes occurring along the eastern and southern boundaries (**Figure 3-1**). Lake Kissimmee, the third largest lake in Florida (Brenner et al. 1990), is the outlet of the UKB to the Kissimmee River. Water throughout the UKB is conveyed to the Kissimmee Chain of Lakes (KCOL)—which includes the Headwaters Revitalization Lakes (Lakes Kissimmee, Hatchineha, Cypress, and Tiger) and the Upper Chain of Lakes (UCOL)—through wetlands, sloughs, and tributary streams. The largest tributaries are Boggy, Shingle, and Reedy creeks as well as Big Bend Swamp. Boggy Creek begins at the northern boundary of the basin in the City of Orlando and flows southward into the north end of East Lake Tohopekaliga. Shingle Creek also originates in the City of Orlando and conveys surface water to Lake Tohopekaliga. Reedy Creek originates in the northwest corner of the basin. Near the mouth, Reedy Creek branches, with most of the flow going to the southern branch (Dead River) into Lake Hatchineha and the remaining flow goes through the northern branch into Lake Cypress. Big Bend Swamp is located southeast of the Alligator Chain of Lakes, is connected by extensive shoreline to Brick Lake, and flows into Lake Gentry. The KCOL are interconnected by a series of canals. Essentially all surface water draining the UKB is funneled to the KCOL, which discharge into the Kissimmee River (Warne et al. 2000).

The LKB encompasses 669 square miles (1,733 km^2) directly north and west of Lake Okeechobee (**Figure 3-1**). The dominant hydrologic feature is the Kissimmee River, which receives flows from the KCOL via the C-38 Canal and discharges south to Lake Okeechobee. The Kissimmee River is the largest tributary to Lake Okeechobee, accounting for approximately 50% of the lake's inflows (SFWMD 2019). The drainage network in the LKB is not well developed and is composed mostly of tributary sloughs. Consequently, the larger UKB is a more important source of water for the Kissimmee River than its tributary watershed.

3.3 Connectivity of the Waterbodies

Connectivity of the surface waterbodies of the Kissimmee Basin has changed over time. Before human modifications, there was a direct connection between the Kissimmee River and several lakes. In 1842, it was possible to travel by boat up the Kissimmee River and across Lakes Kissimmee, Hatchineha, and Cypress to Lake Tohopekaliga (Preble 1945). While well-defined channels did not connect all the lakes, water likely moved between lakes by overland flow during wetter years and by groundwater movement during drier conditions (Warne et al. 2000).

During the 1880s, canals were dredged between lakes in the KCOL as part of a drainage project to reclaim land. Another part of the project dredged a connection between Lake Okeechobee and the Caloosahatchee River. By 1882, it was possible to travel by steamboat from the Town of Kissimmee on Lake Tohopekaliga through Lake Kissimmee then down the Kissimmee River, across Lake Okeechobee, down the Caloosahatchee River to Fort Myers, and ultimately to the Gulf of Mexico.

In the Rivers and Harbors Act of 1902, the United States Congress authorized a federal navigation project with "a channel width of 30 feet and depth of 3 feet at the ordinary stage of the river" from the town of Kissimmee at the northern end of Lake Tohopekaliga through Lakes Cypress, Hatchineha, and Kissimmee and down the Kissimmee River to Fort Basinger. The navigation project involved removal of large woody snags and dredging of channels, as necessary. It was completed by the USACE between 1902 and 1909. In 1927, the USACE conducted the last federal maintenance dredging for the project.

In addition to these large projects, several small projects were conducted by private landowners and local companies. Such projects included small structures on the Zipprer Canal between Lakes Rosalie and Kissimmee and a structure on the Istokpoga Canal between Lake Istokpoga and the Kissimmee River. Other small drainage ditches and levees were constructed by private landowners.

In 1947, hurricanes caused severe flooding in much of South Florida, including the Kissimmee Basin. In response to a request for help from the State of Florida, the United States Congress authorized the C&SF Project in 1949. Features affecting the Kissimmee Basin were authorized in 1954 and constructed between 1962 and 1972. These projects included enlarging existing canals, dredging a new canal to connect Lake Gentry to Lake Cypress, and installing nine water control structures to regulate water levels and flows between the lakes. The structures are responsible for the current path of water movement through the KCOL (**Figure 3-2**). Operation of the structures narrowed the range of water level fluctuation in the lakes, reducing the amount and quality of habitat for fish and wildlife.

Part of the C&SF Project included constructing the C-38 Canal, which channelized the entire length of the Kissimmee River between Lakes Kissimmee and Okeechobee. In addition to the S-65 structure, located at the outlet from Lake Kissimmee, five water control structures (S-65A to S-65E) were installed along the C-38 Canal to step-down water levels and control flow within the river. Channelization and flow regulation greatly altered flow conditions in the river and water levels on the floodplain, which had immediate effects on fish and wildlife. These changes were so dramatic in the LKB that they sparked a grassroots movement ultimately leading to a partnership between SFWMD and USACE to restore the Kissimmee River.

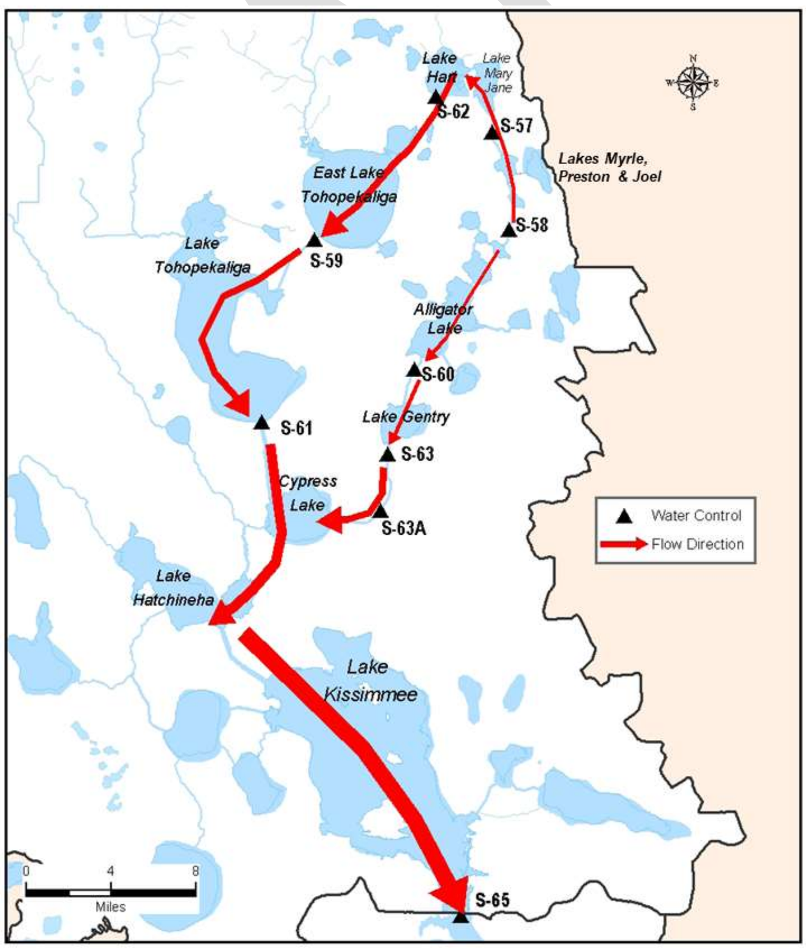


Figure 3-2. Flow of water through the Kissimmee Chain of Lakes.

3.4 Groundwater

The Kissimmee Basin has a complex groundwater system that includes three major hydrogeologic units: the surficial aquifer system (SAS), the intermediate confining unit, and the Floridan aquifer system (FAS). On a broad scale, the FAS is further subdivided into the Upper Floridan aquifer and the Lower Floridan aquifer, which are separated by a semi-confining unit (Miller 1990). These hydrogeologic units have different characteristics that influence the volume of water they contain (**Table 3-1**). Reese and Richardson (2008) redefined these units and provided a hydrogeologic framework for modeling the groundwater system that uses multiple methods for identifying hydrostratigraphic units, including lithologic and geophysical methods. This was used in the modeling done for the Kissimmee River and Chain of Lakes Water Reservations. The thicknesses of the layers vary across the Kissimmee Basin. The magnitude and direction of water interchange between the different aquifers depend on the relative elevation of the potentiometric surfaces of the aquifers and the thickness and vertical permeability of the intervening confining units.

The SAS is primarily recharged by rainfall. Aucott (1988) mapped regional variations in water exchange between the SAS and Upper Floridan aquifer in Florida. The Upper Floridan aquifer in the northern portion of the Kissimmee Basin is recharged by direct downward leakance (e.g., through sinkholes) from the SAS, and where present, through the intermediate confining unit (Aucott 1988, Shaw and Trost 1984, Adamski and German 2004). Recharge to the FAS is high along the Lake Wales, Mount Dora, and Bombing Range ridges where the confining layer is either thin or breached and where elevation differences between the SAS and FAS are greatest (SFWMD 2007). In this area of connection, the SAS consists of fine- to medium-grained quartz sand with varying amounts of silt, clay, and shell deposits.

Table 3-1. Characteristics and potential for water yield from the hydrogeologic layers of the groundwater system in the Kissimmee Basin (Based on: SFWMD 2007).

Hydrogeologic Unit	Characteristics	Potential for Water Yield
Surficial aquifer system	Unconfined aquifer with fine- to medium-grained quartz sand with varying amounts of silt, clay, and crushed shell. Represents the water table.	Yields low quantities of water to wells. Good to fair quality water. Limited to residential supply, lawn irrigation, and small-scale agricultural irrigation.
Intermediate confining unit	Low-permeability sediments and rocks that retard the exchange of water between the surficial and Floridan aquifer systems. Contains interbedded sands, calcareous silts and clays, shell, phosphoric limestone, and dolomite of the Hawthorn group (Miocene).	Not an important source of water, except for a few isolated areas within the Kissimmee Basin.
Floridan Aquifer System		
Upper Floridan aquifer	High permeability with carbonate rock (limestone and dolomite).	Source of virtually all the water used to meet municipal, industrial, and agricultural needs in the Kissimmee Basin.
Semi-confining unit	Less permeable.	Unknown.
Lower Floridan aquifer	High permeability with alternating beds of limestone and dolomite characterized by abundant fractures and solution cavities.	Increasingly used for water supply.

3.5 Reservation and Contributing Waterbodies

Chapter 1 identified the proposed reservation waterbodies. This section provides additional information about the reservation waterbodies and the waterbodies that contribute to them. This section should be reviewed in conjunction with the information, tables, and figures in **Appendix A**. The reservation waterbodies were selected for consideration because they are closely linked and represent substantial water resources important for fish and wildlife. The reservation waterbodies support a world-class sport fisheries population and provide important habitat for several threatened and endangered species. The fish and wildlife resources associated with the reservation waterbodies are described in more detail in **Chapter 4** and **Appendix F**.

Many of the reservation waterbodies are connected; continuously or intermittently receiving substantial inflows (in terms of timing and volume) from other water sources such as wetlands, sloughs, lakes, streams, creeks, canals, and ditches, which are considered contributing waterbodies (**Figure 3-3**). The surface water inflows from these contributing waterbodies are integral to maintaining the hydrologic regime of the reservation waterbodies to ensure protection of fish and wildlife. Under the draft Water Reservation rules, withdrawals from reservation and contributing waterbodies will be regulated, as outlined in Subsection 3.11.5 of the Applicant’s Handbook (SFWMD 2015b). Contributing waterbodies are currently regulated under Subsection 3.3 of the Applicant’s Handbook (SFWMD 2015b); however, additional permitting criteria have been added to ensure protection of water needed for fish and wildlife. In summary, the reservation and contributing waterbodies will be regulated to ensure protection of water needed for fish and wildlife. A more detailed description of the regulatory constraints is provided in **Chapter 5**.

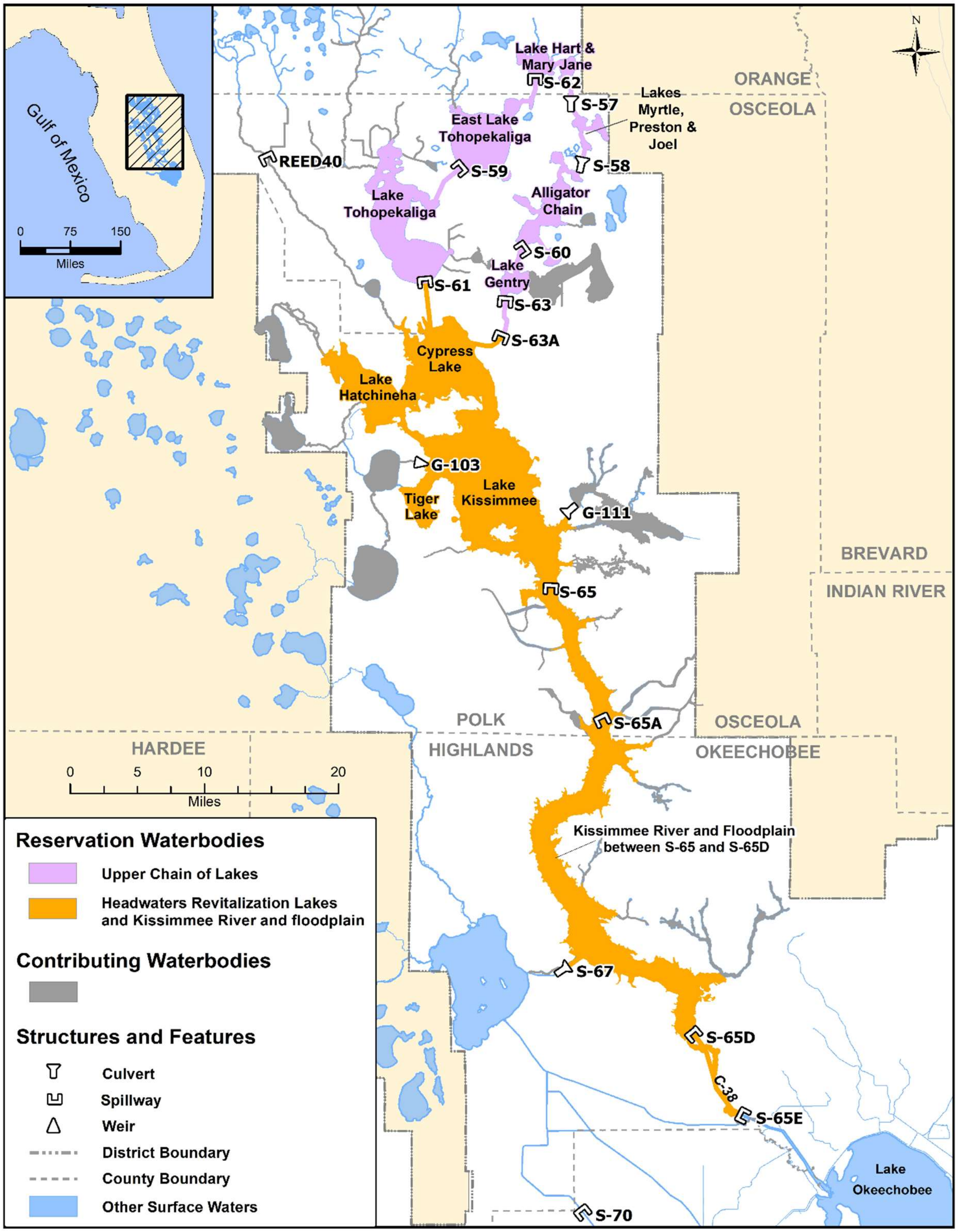


Figure 3-3. Reservation and contributing waterbodies associated with the Kissimmee River and Chain of Lakes Water Reservations.

3.5.1 Kissimmee River

The approximate extent of the Kissimmee River reservation waterbody is shown in **Figure 3-4**. It is bounded by the 100-year flood elevation as delineated by the USACE (1991) between structures S-65 and S-65D and the portion of the Istokpoga Canal and floodplain east of the S-67 structure. It also includes the C-38 Canal and remnant (non-flowing) river channels between the S-65D and S-65E structures.

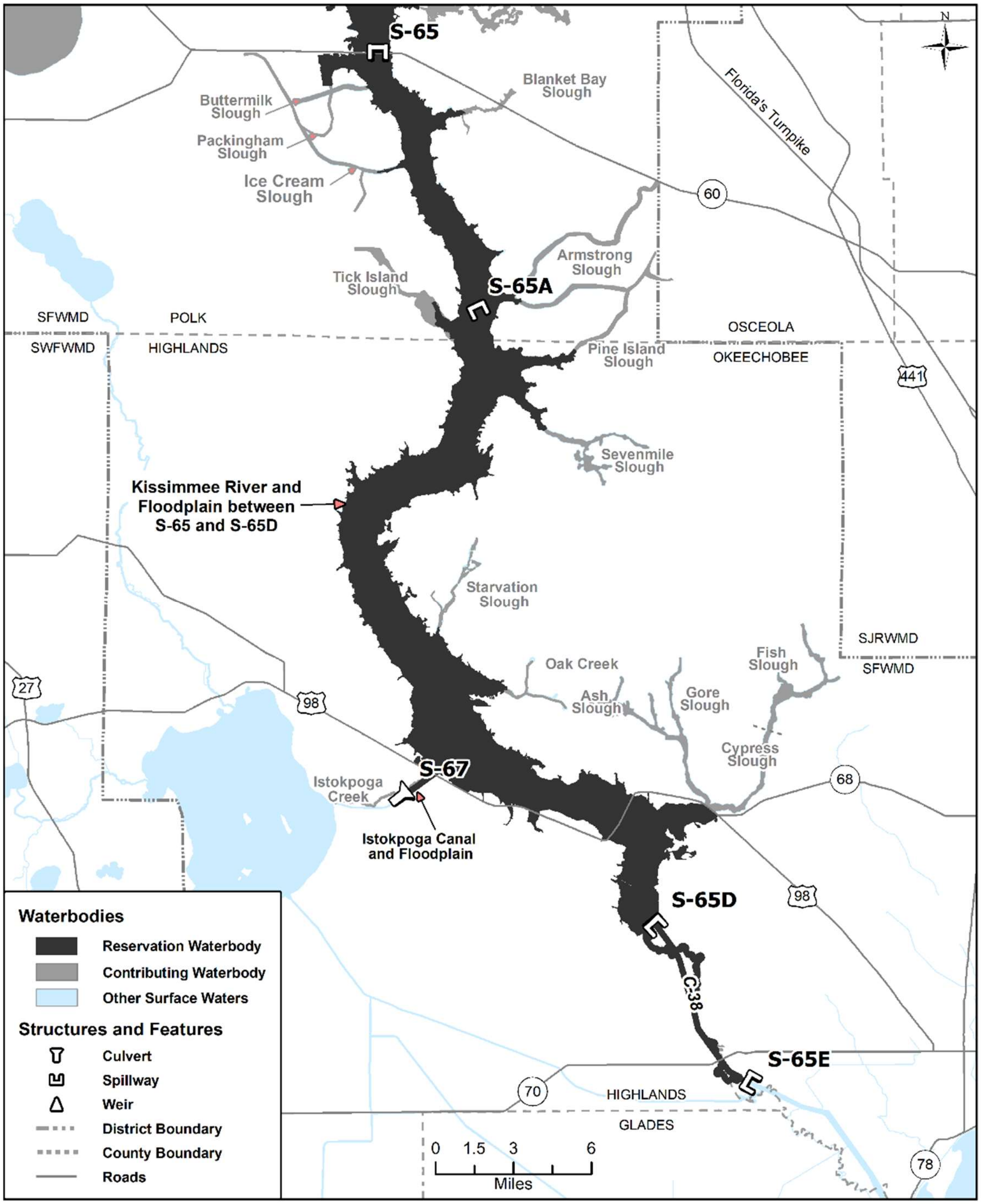


Figure 3-4. Kissimmee River reservation and contributing waterbodies.

As depicted in **Figure 3-4**, numerous contributing waterbodies (tributary systems) discharge surface water to the Kissimmee River and C-38 Canal. On the eastern side of the Kissimmee River/C-38 Canal, contributing waterbodies include Blanket Bay, Armstrong, Pine Island, Sevenmile, Starvation, Ash, Gore, Fish, and Cypress sloughs as well as Oak Creek. On the western side of the Kissimmee River, contributing waterbodies include Packingham, Buttermilk, Ice Cream, and Tick Island sloughs as well as Istokpoga Creek west of the S-67 structure.

Surface water contributions from the KCOL (UCOL and the Headwaters Revitalization Lakes) provide important inflows to the Kissimmee River. To a lesser extent, direct rainfall and runoff from the surrounding watershed within the LKB are sources of water to the Kissimmee River as well. The largest inflow to the Kissimmee River is discharge from the S-65 structure at the southern end of Lake Kissimmee. **Appendix A** contains more information about contributing waterbodies associated with the Kissimmee River.

Channelization of the Kissimmee River reduced the length of the river from a more than 103-mile meandering river channel (166 kilometers (km)) to a relatively straight, almost 56-mile (90-km) long canal from Lake Kissimmee to Lake Okeechobee. Activities associated with the KRRP ultimately will backfill 22 miles (34 km) of the C-38 Canal, re-establish flow to 40 miles (64 km) of river channel, and seasonally inundate almost 25,000 acres (10,100 hectares) of floodplain wetlands (Bousquin et al. 2009).

3.5.2 Headwaters Revitalization Lakes

The approximate landward extent of the Headwaters Revitalization Lakes reservation waterbody (**Figure 3-5**) is the regulated high stage of 54 ft NGVD29 pursuant to the USACE's (1996) HRS. The reservation waterbody includes Lake Kissimmee, Lake Hatchineha, Tiger Lake, Tiger Creek, and Cypress Lake and their interconnecting canals: C-34 (south and north of the S-63A structure), C-35 (south of the S-61 structure), C-36, and C-37. The reservation waterbody also includes Zipprer Canal east of the G-103 structure located downstream of Lake Rosalie, and Jackson Canal south of the G-111 structure.

Contributing waterbodies include Lake Russell, Lower Reedy Creek south of the REED40 structure, Upper Reedy Creek north of the REED40 structure, Bonnet Creek, Lake Marion Creek, Lake Marion, Catfish Creek, Lake Pierce, Zipprer Canal west of the G-103 structure, Lake Rosalie, Weohyakapka Creek, Lake Weohyakapka, Otter Slough, Jackson Canal north of the G-111 structure, Lake Jackson, Parker Hammock Slough, Lake Marian, Fodderstack Slough, and No Name Slough. The northern extent of Bonnet and Upper Reedy creeks, regulated under this rule, terminate at U.S. Highway 192. The western extent of Otter Slough terminates at State Road 60. Parker Hammock Slough is located between Lakes Jackson and Marian. The eastern extent of No Name Slough, located at the southeastern portion of Lake Kissimmee, terminates at the western property boundary of the Three Lakes Wildlife Management Area.

In addition to SAS contributions, direct rainfall, and runoff from the surrounding watershed, the Headwaters Revitalization Lakes reservation waterbodies receive inflow from two other reservation waterbodies that represent the rest of the UCOL: Lake Tohopekaliga and Lake Gentry. Upper and Lower Reedy Creeks and Lake Russell, which provide flows from the northwestern corner of the basin, are collectively major contributing waterbodies to Cypress Lake and Lake Hatchineha. On the west side of the Headwaters Revitalization Lakes reservation waterbodies, there also is flow from Lake Marion via Lake Marion Creek, Lake Pierce via Catfish Creek, and Lake Weohyakapka via Weohyakapka Creek to Lake Rosalie and then to Lake Kissimmee via Zipprer Canal. Flows also come from Tiger Lake via Tiger Creek and Otter Slough. On the east side of the reservation waterbody, there is inflow from Parker Hammock Slough, Lake Marian, Lake Jackson via Jackson Canal, Fodderstack Slough, and No Name Slough. The S-65 structure controls water levels in the Headwaters Revitalization Lakes reservation waterbodies and governs releases from the KCOL to the Kissimmee River.

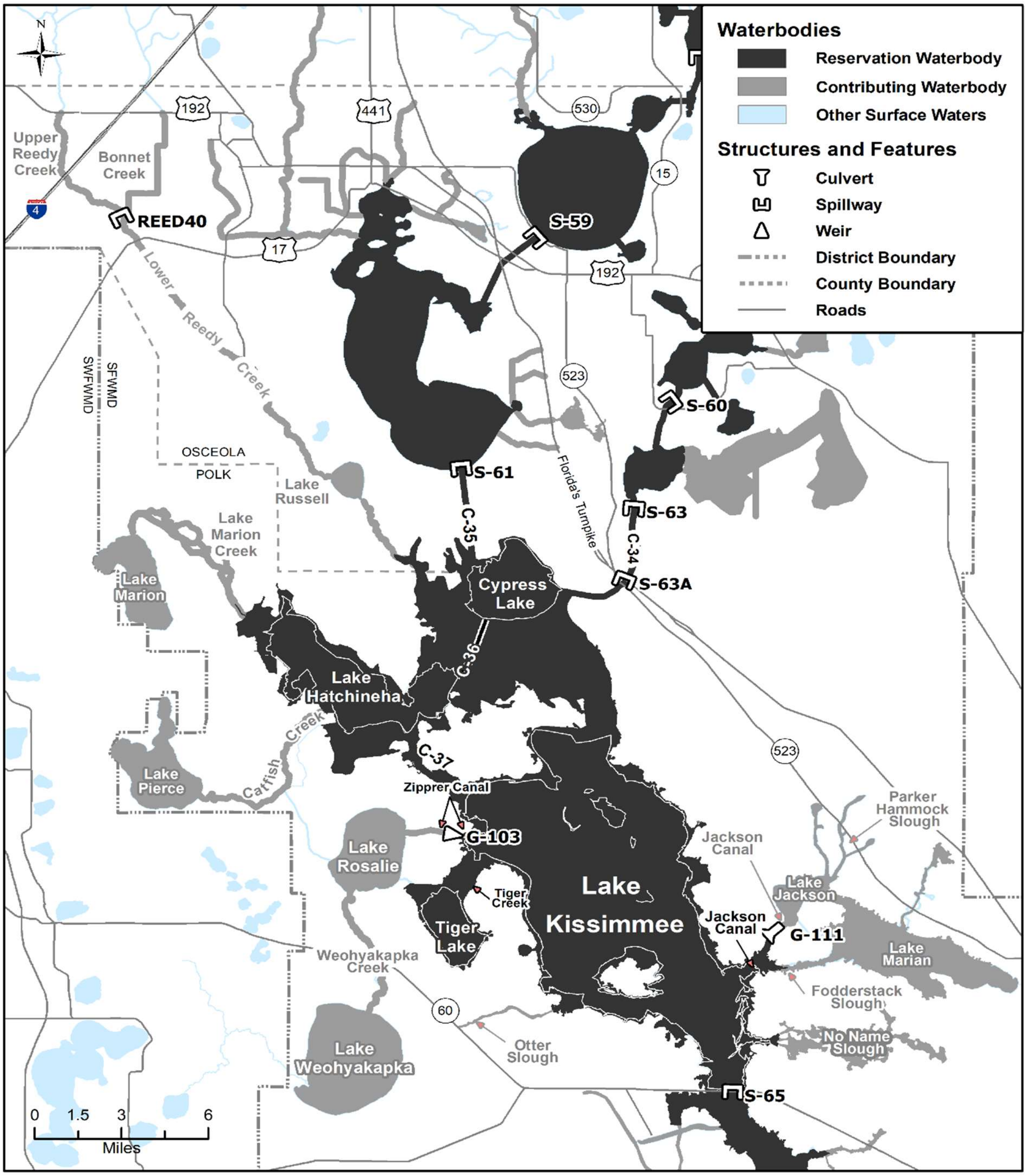


Figure 3-5. Headwater Revitalization Lakes reservation and contributing waterbodies.

In the future, stages within the Headwaters Revitalization Lakes will be raised in accordance with the new HRS, as approved by USACE, to provide the flows necessary to meet the ecological integrity goals of the KRRP. Most of the land surrounding the Headwaters Revitalization Lakes is in public ownership and managed for conservation. Much of the eastern side of Lake Kissimmee is surrounded by two state-owned parcels, Prairie Lakes and Three Lakes Wildlife Management Area. Lake Kissimmee State Park is located between Lake Rosalie and the western shoreline of Lake Kissimmee.

3.5.3 Upper Chain of Lakes

Table 3-2 provides information on the regulated high stage, surface area, volume, and average or maximum depths of each of the reservation waterbodies in the UCOL. While the lakes vary in size and volume, all are relatively shallow. The regulated high stage was used to define the boundaries of the reservation waterbodies to protect and maintain the wetland habitat used by fish and wildlife.

Table 3-2. Stage, surface area, volume, average depth, and maximum depth for the Upper Chain of Lakes reservation waterbodies.

Waterbody	Regulated High Stage[1] (feet)	Area[2] (acres)	Volume[3] (acre-feet)	Average Depth[4] (feet)	Maximum Depth (feet)
Lakes Hart-Mary Jane	61.0	3,811	25,936	7	22
Lakes Myrtle-Preston-Joel	62.0	2,750	10,014	4	11
Alligator Chain of Lakes	64.0	7,401	57,381	8	32
Lake Gentry	61.5	1,947	16,655	9	19
East Lake Tohopekaliga	58.0	12,898	78,424	6	28
Lake Tohopekaliga	55.0	22,018	145,323	7	13

[1] The extent of the reservation waterbodies in the Upper Chain of Lakes is defined as the upper elevation of the stage regulation schedule (in NGVD29) approved by the United States Army Corps of Engineers.
[2] Surface area is at the upper elevation of the stage regulation schedule.
[3] Volume was calculated from stage storage tables.
[4] Average depth was calculated as volume divided by surface area.

3.5.3.1 Lakes Hart-Mary Jane

The approximate extent of the Lakes Hart-Mary Jane reservation waterbody (**Figure 3-6**) is defined by the regulated high stage of 61 ft NGVD29, pursuant to USACE's lake regulation schedule. The Lakes Hart-Mary Jane reservation waterbody includes Lake Hart, Lake Mary Jane, and Lake Whippoorwill. In addition to the lakes proper, the reservation waterbody includes the Whippoorwill, C-29, C-29A (north of the S-62 structure), and C-30 (north of the S-57 structure) canals. The canal features serve as direct hydrologic connections to Lakes Hart and Mary Jane for conveyance of water through the system. Lake Whippoorwill connects directly to the west side of Lake Hart via the Whippoorwill Canal. As there is no structural divide, Lake Whippoorwill and Whippoorwill Canal are considered part of the Lakes Hart-Mary Jane reservation waterbody.

The Lake Hart-Mary Jane reservation waterbody receives inflow from the Lakes Myrtle-Preston-Joel reservation waterbody via the C-30 Canal (**Figure 3-6**). It also receives water from the SAS, direct rainfall, and runoff from the surrounding watershed. The outlet from the Lakes Hart-Mary Jane reservation waterbody is the S-62 structure, located at the southern end of Lake Hart, which controls water levels in Lakes Hart, Mary Jane, and Whippoorwill. Water from the lakes is discharged into the C-29A Canal and conveyed to the East Lake Tohopekaliga reservation waterbody. There are no contributing waterbodies associated with this reservation waterbody.

Rural residential development occurs along a portion of the shoreline of these lakes. South of the C-29 Canal, between Lakes Hart and Mary Jane, are parts of Orange County's Moss Park and the Split Oak Forest Wildlife and Environmental Area.

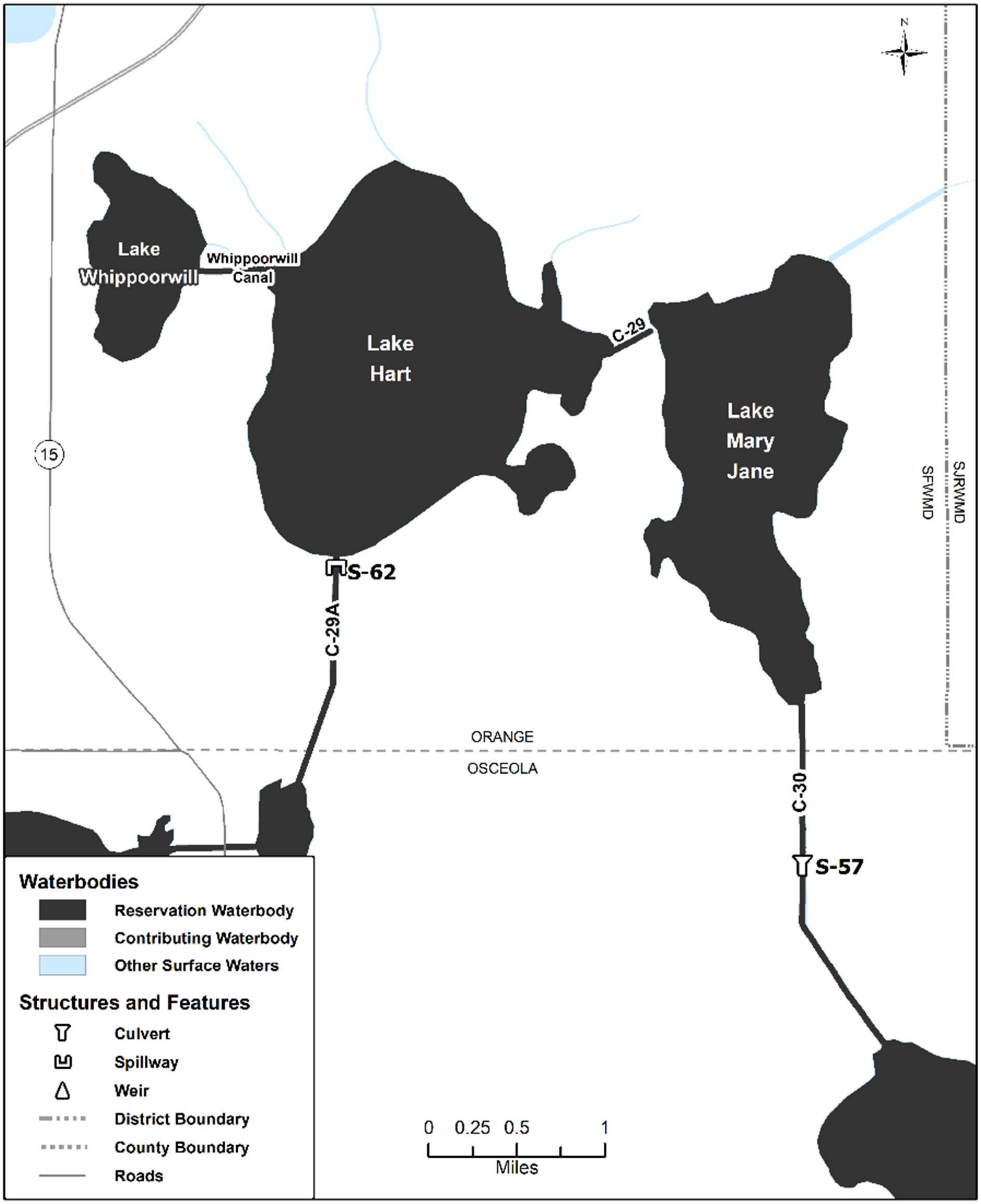


Figure 3-6. Lakes Hart-Mary Jane reservation waterbody (no contributing waterbodies present).

3.5.3.2 Lakes Myrtle-Preston-Joel

The approximate landward extent of the Lakes Myrtle-Preston-Joel reservation waterbody (**Figure 3-7**) is defined by the regulated high stage of 62 ft NGVD29, pursuant to the USACE's lake regulation schedule. The Lakes Myrtle-Preston-Joel reservation waterbody includes Lake Myrtle, Lake Preston, and Lake Joel. In addition to the lakes proper, the reservation waterbody includes the C-30 (south of the S-57 structure), C-32B, C-32C (north of the S-58 structure), and Myrtle-Preston canals. These canals provide a direct hydrologic connection between Lakes Myrtle, Preston, and Joel.

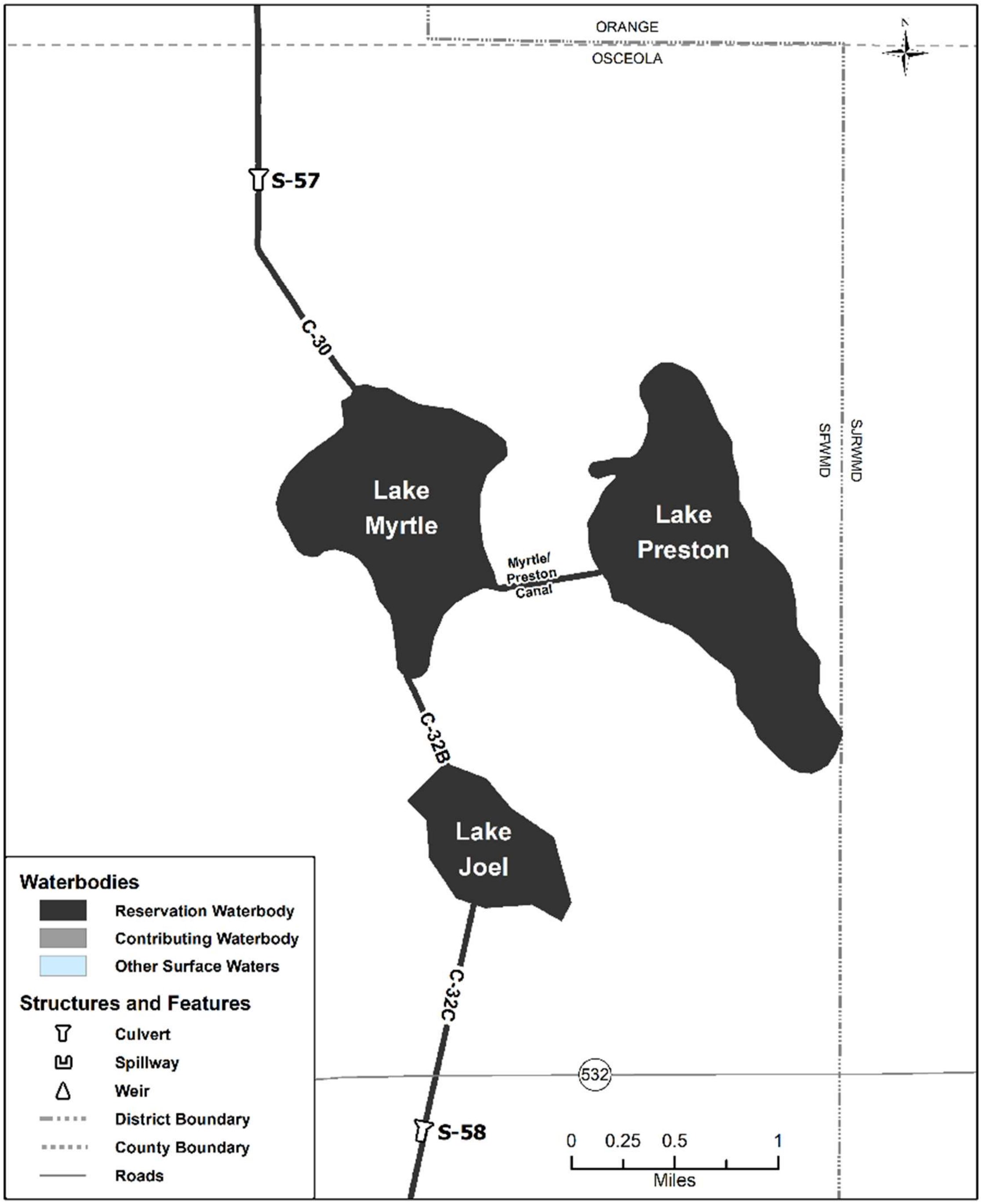


Figure 3-7. Lakes Myrtle-Preston-Joel reservation waterbodies (no contributing waterbodies present).

The main sources of water to the Lakes Myrtle-Preston-Joel reservation waterbody are the SAS, direct rainfall, and runoff from the surrounding watershed. The Lakes Myrtle-Preston-Joel reservation waterbody can receive water from the Alligator Chain of Lakes via the S-58 structure. However, this structure is rarely used and generally serves as a divide structure in the system, with water north of the S-58 structure flowing northward through Lakes Myrtle-Preston-Joel and water south of the structure flowing southward through the system.

Downstream from Lake Myrtle in the C-30 Canal, the principal outlet from the Lakes Myrtle-Preston-Joel reservation waterbody is the S-57 structure, which controls water levels in Lakes Myrtle-Preston-Joel and regulates outflow through the C-30 Canal toward Lake Mary Jane. When water levels in Lakes Myrtle-Preston-Joel are higher than the Alligator Chain of Lakes, water may flow through the S-58 structure into Trout Lake. Ordinarily, this movement of water is prevented by higher water levels in the Alligator Chain of Lakes. There are no contributing waterbodies associated with this reservation waterbody.

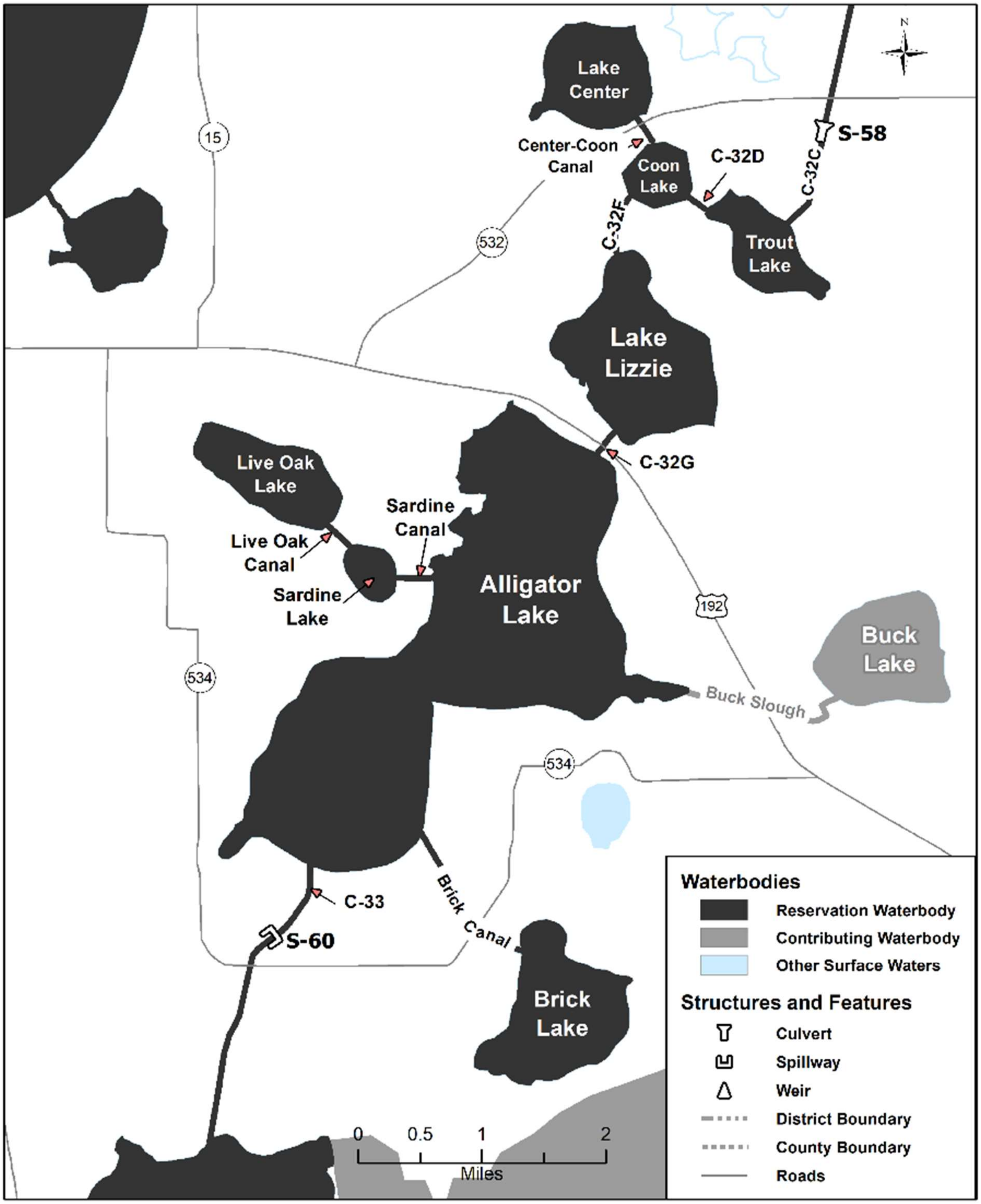
The Lakes Myrtle-Preston-Joel watershed is relatively small but approximately nine times the area of the lakes themselves. The shorelines of these lakes are within Osceola County's Urban Growth Area and are in the process of being converted into residential and mixed uses. Several environmental resource and water use permits have been issued for a development called Sunbridge.

3.5.3.3 Alligator Chain of Lakes

The approximate extent of the Alligator Chain of Lakes reservation waterbody (**Figure 3-8**) is defined by the regulated high stage of 64 ft NGVD29, pursuant to the USACE's lake regulation schedule. The Alligator Chain of Lakes reservation waterbody includes Lake Center, Coon Lake, Trout Lake, Lake Lizzie, Live Oak Lake, Sardine Lake, Alligator Lake, and Brick Lake. In addition to the lakes proper, the reservation waterbody includes multiple canals: C-32C south of the S-58 structure, C-32D, Center-Coon, C-32F, C-32G, Live Oak, Sardine, Brick, and C-33 north of the S-60 structure. Live Oak Lake and Sardine Lake connect directly to the west side of Alligator Lake via the Live Oak and Sardine canals. As there are no control structures within these canals, Live Oak and Sardine Lakes are considered part of the Alligator Chain of Lakes reservation waterbody. All these waterbodies have direct connections to the upstream, downstream, or lateral waterbodies by means of a canal. Buck Lake and Buck Slough are contributing waterbodies because their hydrologic connection to Alligator Lake occurs through an ephemeral slough system rather than directly through a canal.

The sources of water to the Alligator Chain of Lakes reservation waterbody are the SAS, direct rainfall, and runoff from the surrounding watershed. Some inflow from the Lakes Myrtle-Preston-Joel reservation waterbody is possible under certain conditions.

Located at the southern end of Alligator Lake, the primary outlet from the Alligator Chain of Lakes is the S-60 structure, which controls water levels in all the Alligator Chain of Lakes waterbodies and releases water to Lake Gentry. Some surface water releases can be made from the north end of the Alligator Chain of Lakes reservation waterbody through the S-58 structure to the Lakes Myrtle-Preston-Joel reservation waterbody. Extensive residential development exists along some of the shorelines in the Alligator Chain of Lakes.



699
700 Figure 3-8. Alligator Chain of Lakes reservation and contributing waterbodies.

3.5.3.4 Lake Gentry

The approximate landward extent of the Lake Gentry reservation waterbody (**Figure 3-9**) is defined by the regulated high stage of 61.5 ft NGVD29, pursuant to USACE's lake regulation schedule. The reservation waterbody includes a single lake - Lake Gentry. In addition to the lake proper, the reservation waterbody includes the C-34 Canal north of the S-63 structure and the C-33 Canal south of the S-60 structure.

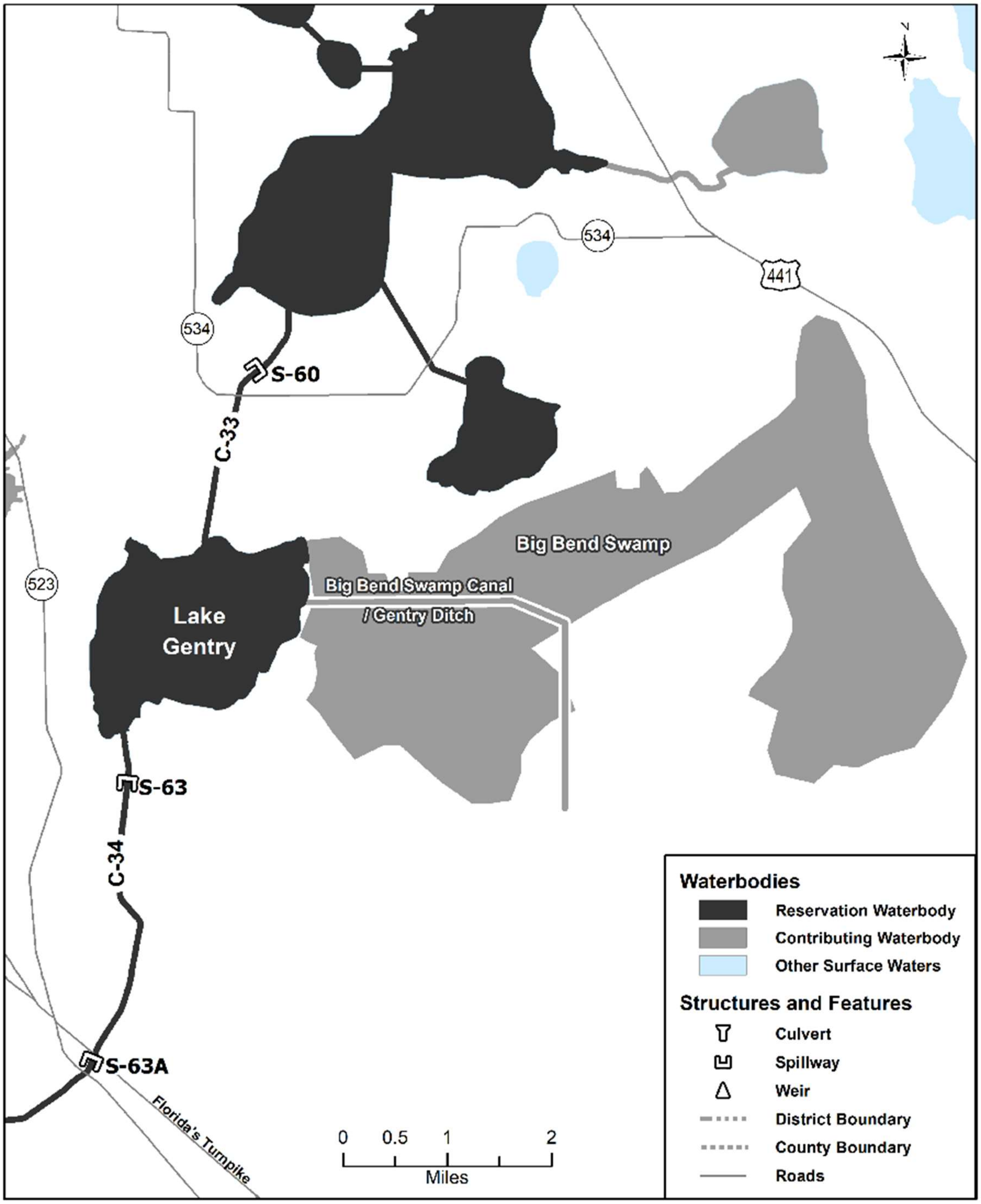


Figure 3-9. Lake Gentry reservation and contributing waterbodies.

Big Bend Swamp and Big Bend Swamp Canal/Gentry Ditch are contributing waterbodies that drain into the east side of Lake Gentry. Big Bend Swamp Canal/Gentry Ditch drains both wetland and uplands downstream to Big Bend Swamp. The southeastern extent of Big Bend Swamp Canal/Gentry Ditch terminates at the line between Sections 23 and 26, Township 27, Range 31.

In addition to SAS contributions, direct rainfall, and runoff from the surrounding watershed, Lake Gentry receives surface water inflows from the Alligator Chain of Lakes reservation waterbody through the C-33 Canal and from Big Bend Swamp along the eastern shore of the lake.

Water levels in Lake Gentry are regulated by the S-63 structure, located approximately 2,900 ft downstream of the lake on the C-34 Canal. This structure also controls releases from Lake Gentry into Lake Cypress via a second structure, S-63A, which is approximately halfway between the S-63 structure and Lake Cypress. The S-63A structure is used to step-down stages in the C-34 Canal. The shoreline of Lake Gentry is relatively undeveloped, with only some rural lakeside residences.

3.5.3.5 East Lake Tohopekaliga

The approximate landward extent of the East Lake Tohopekaliga reservation waterbody (**Figure 3-10**) is defined by the regulated high stage of 58 ft NGVD29, pursuant to USACE's lake regulation schedule. The East Lake Tohopekaliga reservation waterbody includes East Lake Tohopekaliga, Lake Runnymede, Fells Cove, and Ajay Lake. In addition to the lakes proper, the reservation waterbody includes multiple canals: C-29A south of the S-62 structure, C-29B, Runnymede, and C-31 northeast of the S-59 structure. Ajay Lake and Fells Cove are upstream of East Lake Tohopekaliga and directly connected through the canals mentioned above. Lake Runnymede is southeast of East Lake Tohopekaliga and directly connected to the lake by the Runnymede Canal. As there is no structural divide, Lake Runnymede and Runnymede Canal are considered part of the East Lake Tohopekaliga reservation waterbody. The reservation waterbody does not include the stormwater management lakes located along the southern shoreline of East Lake Tohopekaliga within the City of St. Cloud.

In addition to SAS contributions, direct rainfall, and runoff from the surrounding watershed, there are two major inflows into East Lake Tohopekaliga. The first is Boggy Creek, which enters the lake from the northwestern corner. The second is Ajay Lake via the East Tohopekaliga Canal (C-29A Canal) from the Lakes Hart-Mary Jane reservation waterbody. Minor inflow occurs from Lake Runnymede on the southeast shore.

The S-59 structure, located at the southern end of East Lake Tohopekaliga, controls water levels in East Lake Tohopekaliga, Fells Cove, Ajay Lake, and Lake Runnymede. The S-59 structure releases water into the C-31 (St. Cloud) Canal, which enters the Lake Tohopekaliga reservation waterbody through Goblet's Cove.

Extensive residential development exists along the shoreline of these lakes. It is most intensely developed along the south shore of East Lake Tohopekaliga, where the City of St. Cloud is located. More recent residential development has occurred in the northeastern portion of this reservation waterbody, around Fells Cove.

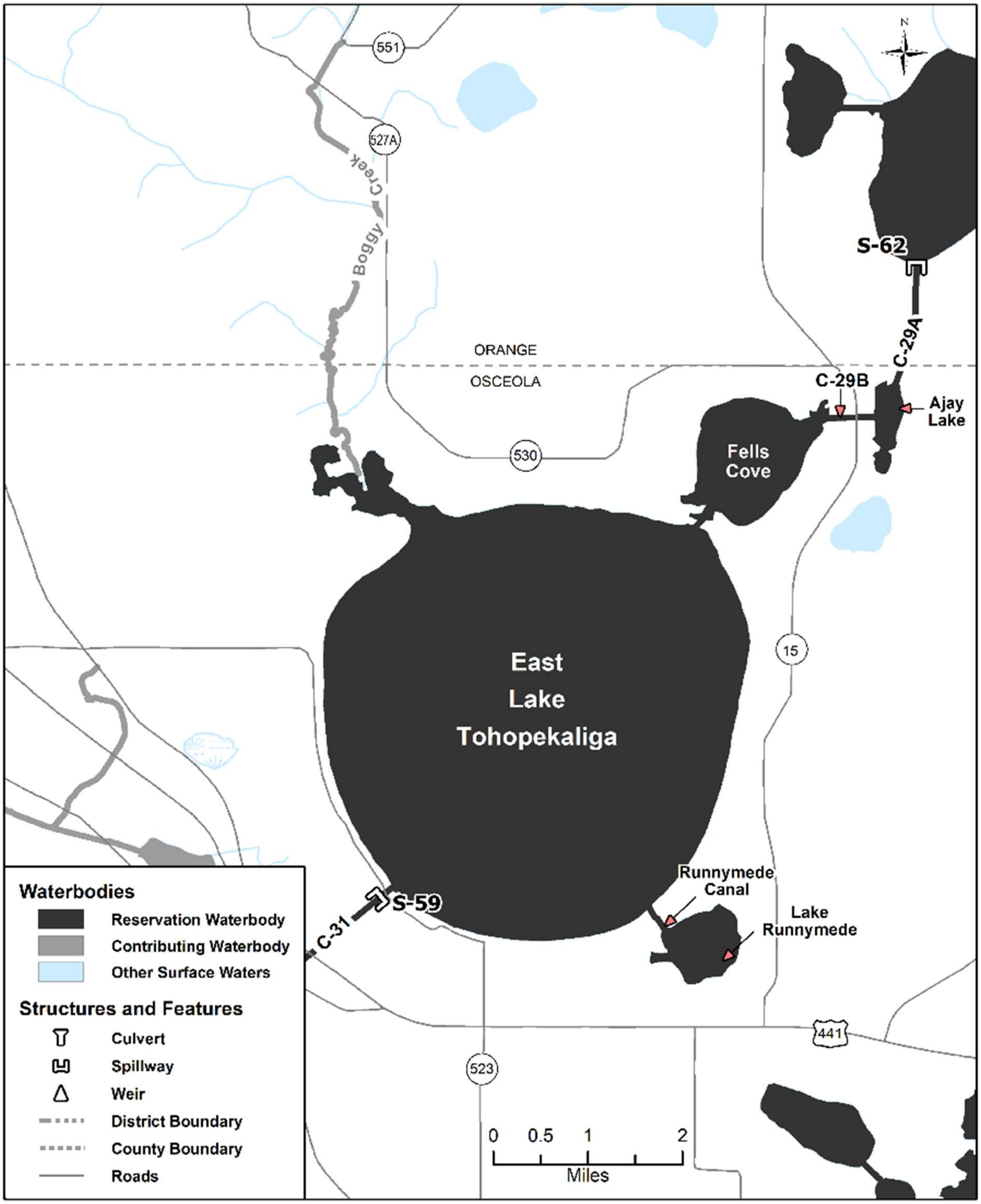


Figure 3-10. East Lake Tohopekaliga reservation and contributing waterbodies.

3.5.3.6 Lake Tohopekaliga

The approximate landward extent of the Lake Tohopekaliga reservation waterbody (**Figure 3-11**) is defined by the regulated high stage of 55 ft NGVD29, pursuant to USACE's lake regulation schedule. The Lake Tohopekaliga reservation waterbody is the largest reservation waterbody within the UCOL, covering approximately 22,000 acres (8,900 hectares; **Table 3-2**). The reservation waterbody also includes the C-31 Canal southwest of the S-59 structure.

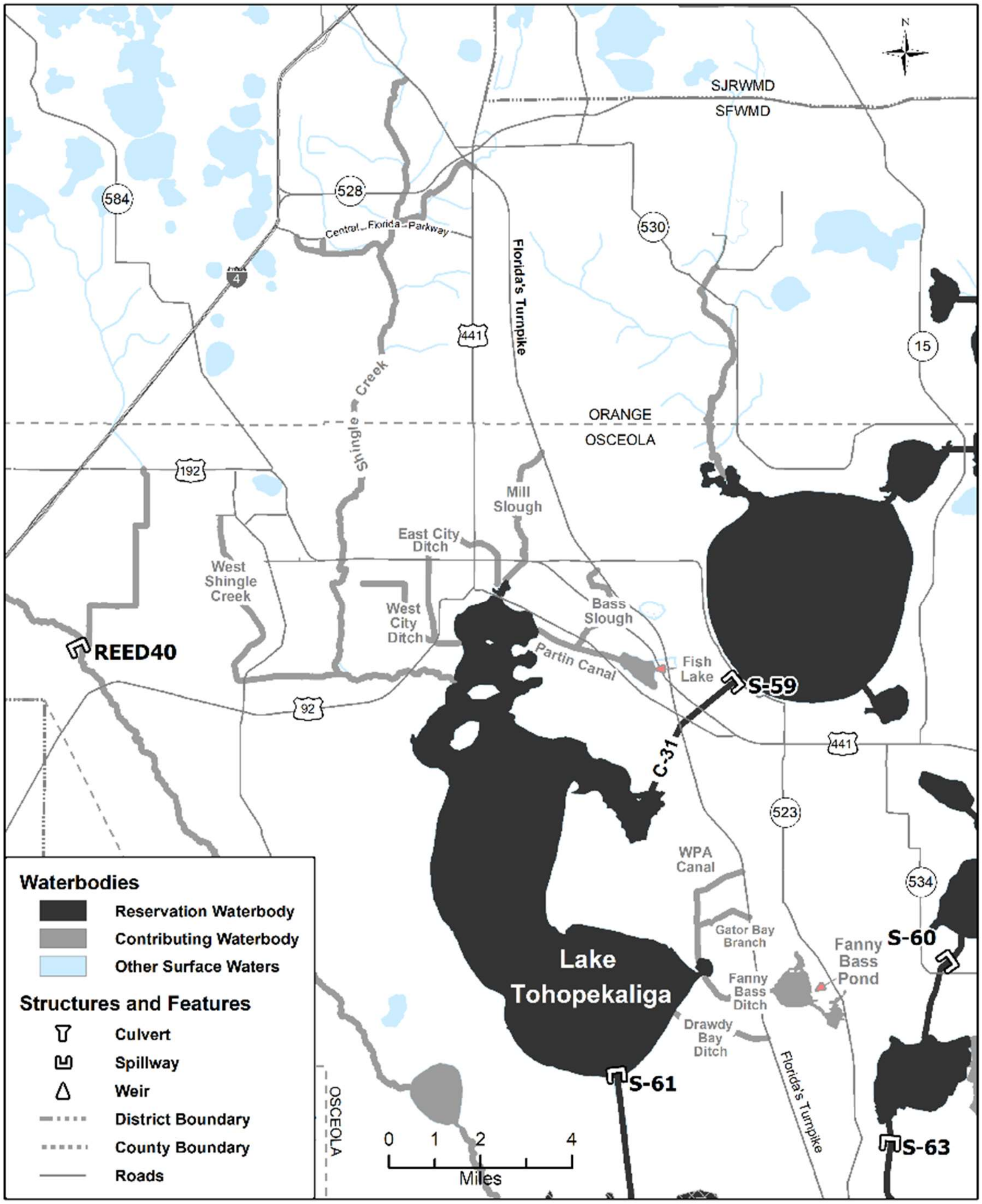


Figure 3-11. Lake Tohopekaliga reservation and contributing waterbodies.

In addition to SAS contributions, direct rainfall, and runoff from the surrounding watershed, the Lake Tohopekaliga reservation waterbody receives inflow from the East Lake Tohopekaliga reservation waterbody via the C-31 Canal. There also are major inflows from a major contributing waterbody—Shingle Creek, which flows from the City of Orlando southward and enters Lake Tohopekaliga at its northern end. Additional contributing waterbodies include Fish Lake, Mill Slough, West Shingle Creek, Fanny Bass Pond, Bass Slough, Partin Canal, East City Ditch, West City Ditch, Works Progress Administration Canal, Gator Bay Branch, Fanny Bass Ditch, and Drawdy Bay Ditch. Some of these contributing waterbodies discharge to this reservation waterbody via existing channelized conveyance systems. The northern extent of Shingle Creek, Mill Slough, Bass Slough, Works Progress Administration Canal, Drawdy Bay Ditch, and Gator Bay Branch contributing waterbodies terminate at Florida's Turnpike. The northwestern branch of Shingle Creek ends at the Central Florida Parkway. West Shingle Creek terminates at Camelot Country Way. The eastern extent of the Fanny Bass Pond wetland complex terminates at County Road 523. The S-61 structure controls water levels in the Lake Tohopekaliga reservation waterbody and releases water into the C-35 (Southport) Canal, which flows into Lake Cypress.

The City of Kissimmee is located on the northwest shore of Lake Tohopekaliga. Extensive residential and commercial development exists around much of the lake. The surrounding areas are within the Osceola County Urban Growth Area.

CHAPTER 4: FISH AND WILDLIFE RESOURCES AND HYDROLOGIC REQUIREMENTS

4.1 Kissimmee River and Headwaters Revitalization Lakes

Following completion of the C-38 Canal in 1971 by the C&SF Project, numerous state and federal planning and feasibility studies (USACE 1991, 1996), demonstration projects (e.g., Loftin et al. 1990a; Toth 1991, 1993), modeling efforts (e.g., Loftin et al. 1990b), legislative actions, appropriations, and other actions led to the authorization of the KRRP. The *Central and Southern Florida Project Final Integrated Feasibility Report and Environmental Impact Statement Environmental Restoration Kissimmee River, Florida* (USACE 1991) describes the recommended plan for the KRRP, including an environmental impact statement (EIS) that addresses the National Environmental Policy Act, Endangered Species Act, and other concerns. The United States Fish and Wildlife Service (USFWS) *Fish and Wildlife Coordination Act Report on the Kissimmee River Restoration Project* is included in the USACE (1991) report as Annex E. In 1992, the United States Congress passed the Water Resources Development Act (Public Law 102-580). Section 101 of the act authorizes the KRRP and its Headwaters Revitalization components, including the HRS. The KRRP represents the culmination of considerable public participation and investment. The final cost to restore the Kissimmee River currently is estimated at almost $800 million. The project is a partnership between the SFWMD and USACE and is equally cost-shared between the state and federal governments.

An integral operational component of the KRRP was the development of a new regulation schedule for the S-65 structure at the outlet from the Headwaters Revitalization Lakes to the Kissimmee River. The new HRS was designed to provide the flows necessary to meet the KRRP's hydrologic and ecological integrity goals. The HRS was authorized by Congress in 1992 as part of the Water Resources Development Act and the KRRP. In 1994, the USFWS completed the *Fish and Wildlife Coordination Act Report on Kissimmee Headwaters Lakes Revitalization Plan* (USFWS 1994) pursuant to the requirements of the Fish and Wildlife Coordination Act and the Endangered Species Act of 1973. The technical analysis associated with the HRS was completed in April 1996 and is described in the *Central and Southern Florida Project, Kissimmee River Headwaters Revitalization Project: Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement* (USACE 1996). In November 1996, the USACE issued its record of decision approving the recommended plan, including the construction plan and schedule change, described in USACE (1996), finding it "to be economically justified, in accordance with environmental statutes, and in the public interest."

The HRS will increase storage in the Headwaters Revitalization Lakes to retain water during wetter periods for release, as needed, to the river in order to replicate historical flow characteristics. A major component of the state's investment in the project was the acquisition of land to create additional storage to allow natural inundation of the Kissimmee River floodplain.

Reconstruction of the river has been occurring in phases since the late 1990s. At the time of this writing, the physical project is expected to be complete in December 2020. Until KRRP construction is complete, the HRS cannot be fully implemented. Following completion of Phase I construction in 2001, an interim regulation schedule for the S-65 structure has been used to provide partial floodplain inundation and restore habitat in the reconnected river channels. This interim schedule will continue to be used until construction is complete and the HRS can be fully implemented.

Fish, wildlife, and habitat responses within the KRRP areas and unrestored control areas are being tracked by the SFWMD's Kissimmee River Restoration Evaluation Program using river/floodplain restoration performance measures. Monitoring results for the river channel and floodplain have been reported annually in the *South Florida Environmental Report* since 2005 as new data become available; Koebel et al. (2020) contains the most recent monitoring data and trends. Responses also were summarized in a special section of the international peer-reviewed journal *Restoration Ecology* in 2014, including results for hydrology (Anderson 2014a), river channel geomorphic characteristics of habitat (Anderson 2014b), dissolved oxygen (Colangelo 2014), vegetation in the river channel (Bousquin and Colee 2014) and floodplain (Spencer and Bousquin 2014), aquatic macroinvertebrates (Koebel et al. 2014), fish (Jordan and Arrington 2014), and wading birds and waterfowl (Cheek et al. 2014). To date, ecological responses to the first three construction phases have been most pronounced in the river channel. Floodplain metrics are expected to improve dramatically following implementation of the HRS.

To fully capitalize on federal and state authorizations and associated funding, it is essential to ensure the water needed to achieve hydrologic improvements to meet the KRRP's ecological integrity goal is reserved for its intended use (including protection of fish and wildlife) and not allocated to consumptive uses. As a result, the SFWMD initiated the Water Reservation rule development process for the Kissimmee River and Chain of Lakes.

This chapter is an update of the material from the 2009 draft technical document (SFWMD 2009) for the Kissimmee River and Chain of Lakes Water Reservations. The technical foundation is the same and, therefore, has been peer reviewed (**Appendix E**).

4.2 Kissimmee River Fish and Wildlife Resources and Hydrologic Requirements

This section and **Appendix F** describe the vegetation and fish and wildlife resources that occur in the Kissimmee River and floodplain. This section includes fish and bird communities; **Appendix F** includes plant communities, amphibians and reptiles, and mammals as well as detailed species lists for all animal taxa described here and in **Appendix F**. The focus of these descriptions is on higher taxa that depend on the river and floodplain to meet their reproductive, feeding, and other survival needs for one or more life cycle stages. Hydrologic requirements of the major floodplain vegetation groups as well as fish and wildlife also are discussed here and in **Appendix F**. Additional information on Kissimmee River fish and wildlife and associated habitat resources of the Kissimmee River and floodplain can be found in USACE (1991) Sections 9.8.3 and 9.8.4 and Annex D; Koebel et al. (2014; invertebrates); Cheek et al. (2014; waterbirds); Spencer and Bousquin (2014; floodplain vegetation); Bousquin and Colee (2014; river channel vegetation); Colangelo (2014; dissolved oxygen); Jordon and Arrington (2014; piscivorous fish); Anderson et al. (2005); Koebel and Bousquin (2014); and Bousquin et al. (2005b).

Important native fish and wildlife resources were associated with the Kissimmee River prior to its channelization. Many species of fish and wildlife declined in abundance or disappeared from the area after the river was channelized and its floodplain drained (Toth 1993). Monitoring conducted by the SFWMD's Kissimmee River Restoration Evaluation Program tracks the fish and wildlife currently associated with the Kissimmee River and changes occurring during the transition period between the start of construction and future restoration. Since completion of Phase I construction of the KRRP in 2001, which restored flow to an initial 14 miles of river channel, there were increases in the use of the river channel and parts of the floodplain by some fish and wildlife (Bousquin et al. 2007, 2009). These changes, which are consistent with those predicted by Kissimmee River Restoration Evaluation Program performance measures for the river channel (Anderson et al. 2005), demonstrate the linkage between hydrology in the river channel and floodplain and their use by fish and wildlife, which is the basis for the river restoration effort. Less robust changes have occurred on the floodplain compared to the river channel because the project has not yet provided sufficient floodplain inundation. Floodplain recovery is expected after implementation of the HRS with appropriate water management operations.

4.2.1 Kissimmee River Fish

A total of 52 species of fish have been collected from the Kissimmee River and its floodplain (**Appendix F**, Table F-2). Of these species, 39 were reported in the river before channelization (Florida Game and Fresh Water Fish Commission 1957). Although there were significant changes in the structure of the fish community following channelization (described below), only one species, the blackbanded darter (*Percina nigrofasciata*), was lost (Trexler 1995). Six exotic species have invaded or been released into the system since the 1950s. Fish species occurring in the Kissimmee River system represent a range of trophic levels (herbivore, piscivore, omnivore, invertivore, planktivore, and detritivore), consume foods from both aquatic and terrestrial environments (Karr et al. 1986), and serve as a critical link in the energy pathway between primary producers and higher trophic level consumers, including amphibians, reptiles, and birds (Karr et al. 1992, Gerking 1994).

Most fish species in the Kissimmee River use the floodplain for feeding and reproduction (Trexler 1995). This is shown by the guild classification in **Appendix F**, Table F-2. Fifteen native species belong to the Off-channel Specialist Guild, which contains species usually found in off-channel habitats or are limited to non-flowing vegetated waters throughout their life. Many of these species are small forage fish, such as mosquito fish (*Gambusia holbrooki*) and the least killifish (*Heterandria formosa*). These fish are important prey for game fish and wading birds foraging on the floodplain. Another 23 native species and 5 exotic species belong to the Off-channel Dependent Guild, whose members require access to or use of off-channel habitats or are limited to non-flowing, vegetated waters for some portion of their life cycle. The 38 native species that depend on an inundated floodplain for some stage in the life cycle constitute 74% of the species currently in the river.

4.2.1.1 Hydrologic Requirements of Kissimmee River Fish

The species that compose riverine fish communities are adapted to seasonally fluctuating flow (Poff and Allan 1995, Poff et al. 1997) and use inundated floodplain habitat during the seasonal flood pulse of water onto and off the floodplain, a pattern seen in other medium to large rivers (Welcomme 1979, Junk et al. 1989). Before channelization, the Kissimmee River experienced a flood pulse that began with high flows near the end of the summer-fall wet season. The pulse inundated much of the floodplain for an extended period of time during most years (Toth et al. 2002). The pulse had a gradual recession over the dry season, with lower flow continuing until the next flood event.

Seasonality, an important aspect of the flood pulse in the Kissimmee River, is reflected in the timing of the maximum and minimum average monthly flows and a gradual transition from the maximum to the minimum (recession). If the timing of this seasonal pattern is notably altered, organisms may not be able to reproduce, survival of progeny may suffer, and other life-history requirements may not be met. In Florida rivers, Bonvechio and Allen (2005) found that recruitment of sunfish (Centrarchidae) was affected by the timing of high flows. High flows during or soon after spawning could damage nests or displace offspring. High flows before spawning in the pre-regulated system allowed adults access to the floodplain where more invertebrate prey would be available. Three or more consecutive years with disrupted seasonality of flow could reduce the abundance of sunfish (Bonvechio and Allen 2005).

Off-channel dependent fish need seasonally high water levels above the banks of the river channel to access the floodplain for reproduction and foraging (Scheaffer and Nickum 1986, Winemiller and Jepsen 1998; **Figure 4-1**). For example, largemouth bass (*Micropterus salmoides*) require water depths of 2 to 4 ft (60 to 120 cm) for nest construction, and their fry require densely vegetated habitat as refugia (**Appendix F**, Table F-2). The time required for this process is as follows: nest construction and spawning, 1 to 3 days; egg incubation, 3 to 4 days; time for eggs to hatch and for hatchlings to fully develop as fry (swim-up), 5 to 8 days; parental guarding of fry, 7 to 14 days; and schooling by fry after abandonment, 26 to 31 days.

Therefore, bass require appropriate inundation characteristics for 42 to 60 days for a single spawning event that may occur between December and May. In addition to largemouth bass, other off-channel dependent fish taxa spawn throughout the year, especially several ecologically and sociopolitically significant game fish (**Appendix F**, Table F-2). For instance, bluegill (*Lepomis macrochirus*) and redear sunfish (*Lepomis microlophus*) are known to spawn in Florida between February and October, whereas spotted sunfish (*Lepomis punctatus*) spawn between May and November (Carlander 1977). When all centrarchid taxa are considered (including largemouth bass), spawning may occur during any month of the year (**Appendix F**, Table F-2).

High water levels are needed to create hydroperiods and water depths to maintain large areas of the Broadleaf Marsh plant community, which provides forage and refuge from predation for early life stages of large-bodied fish (Savino and Stein 1982, Toth 1990, Winemiller and Jepsen 1998). Inundation of the floodplain also creates foraging opportunities by creating habitat for the secondary production of aquatic invertebrates and forage fish (Gladden and Smock 1990, Winemiller and Jepsen 1998). In tropical floodplain rivers, the yield of fish in one year is positively related to the area of floodplain inundated in previous years (Welcomme and Hagborg 1977).

When the floodplain is not inundated, flow is still required to maintain habitat characteristics in the river channel. Based on studies conducted during the Pool B Demonstration Project, a minimum flow of 250 cubic feet per second (cfs) was needed during the summer to maintain dissolved oxygen levels suitable for fish (Wullschleger et al. 1990a); minimum sustained flows of ≥247 cfs were needed to preserve habitat quality (Wullschleger et al. 1990b). These flows also are needed to maintain the river channel substrate and create an appropriate distribution of vegetation within the river channel.

Water velocity appears to be a factor in the protection of fish and wildlife. Based on observations during the Pool B Demonstration Project, mean channel velocities that exceeded 1.6 feet per second (ft/s) (50 centimeters per second [cm/s]) caused fish to seek refuge or possibly migrate (Wullschleger et al. 1990b, Miller 1990). This value agrees with reports from other systems for two species that occur in the Kissimmee River. For the redbreast sunfish (*Lepomis auritus*), water velocities up to 1.1 ft/s (35 cm/s) are suitable for adults and juveniles, velocities up to 0.7 ft/s (20 cm/s) are suitable for fry and embryo stages, and velocities >1.1 ft/s (35 cm/s) reduce abundance (Aho et al. 1986). For the bluegill, adults prefer current velocities <0.3 ft/s (10 cm/s) but will tolerate up to 1.5 ft/s (45 cm/s) (Stuber et al. 1982a). For largemouth bass, optimal velocities are <0.19 ft/s (6 cm/s), and velocities >0.65 ft/s (20 cm/s) are unsuitable (Stuber et al. 1982b).

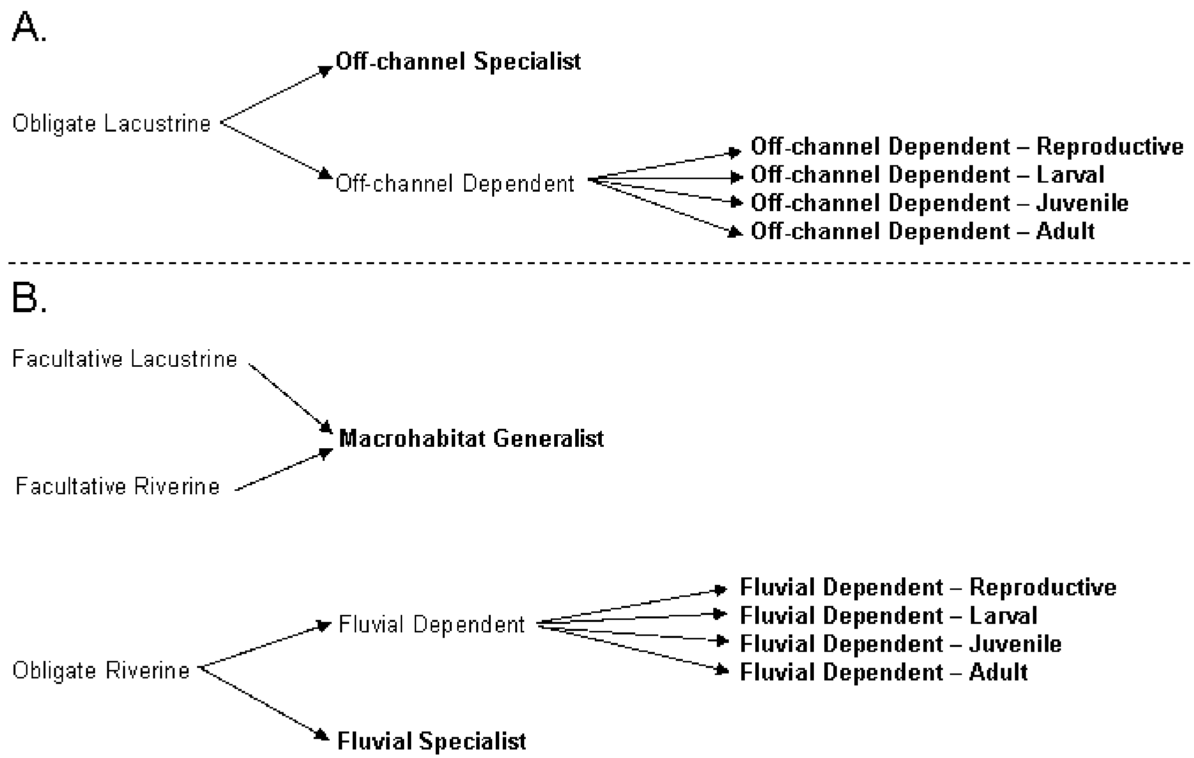


Figure 4-1. Schematic representation of modified macrohabitat guild structure (Derived from: Bain 1992).

(A) New guild categories based on dependence of associated taxa on off-channel habitat. The new Off-channel Dependent category includes species found in a variety of habitats but require access or use of off-channel habitats, or are limited to nonflowing, vegetated waters at some point in their life cycle. These species may have significant riverine populations during particular life history stages. The Off-channel Specialist category refers to species that usually are found only in off-channel habitats or species that are limited to non-flowing, vegetated habitats throughout life. Occasionally, individuals may be found in the river channel, but most information about these fish pertains to off-channel habitat.
(B) Original macrohabitat guild classification developed by Bain (1992).

4.2.2 Kissimmee River Birds

The Kissimmee River and associated floodplain historically served as important breeding and wintering grounds for large populations of wetland-dependent wading birds (Ciconiiformes), waterfowl (Anseriformes), shorebirds (Charadriiformes), marsh birds (Podicipadidae, Ardeidae, Rallidae, and Aramidae), and song birds (Passeriformes) (National Audubon Society 1936-1959, Florida Game and Fresh Water Fish Commission 1957, Weller 1995, Williams and Melvin 2005). Populations of many of these bird groups were negatively impacted by channelization, which substantially reduced the quantity and quality of marsh habitat by the early 1970s (Perrin et al. 1982, Toth 1993, Weller 1995). Pre- and post-channelization data indicated a 92% reduction in the mean number of waterfowl use days for all ducks (Anatinae) and American coots (*Fulica americana*) (Perrin et al. 1982). Prior to channelization, wading bird breeding colonies formed more regularly, were larger, and were not dominated by cattle egrets (*Bubulcus ibis*) (National Audubon Society 1936-1959). Post-channelization changes in hydrology, vegetation communities, and associated prey communities are believed to have contributed to the reduction of wading bird and waterfowl use of the river. This is supported by the latest Kissimmee River Restoration Evaluation Program monitoring data, which indicate the abundance of wading birds and waterfowl has increased over baseline (channelized) conditions since completion of Phase I restoration in 2001 (Cheek et al. 2014, Koebel et. al. 2020). Completion of this phase resulted in periodic flooding of more than 5,792 acres (2,344 hectares) of former pasture and uplands as well as the partial return of historical hydrologic conditions and vegetation communities (Bousquin et al. 2007, 2009). Additionally, this likely produced a concomitant effect on prey populations of invertebrates and small fish (Koebel et al. 2020).

Wetland habitats of the Kissimmee River channel and floodplain now support at least 159 bird species, 66 of which are considered wetland-dependent during some portion of their life cycles (**Appendix F**, Table F-4). This number includes 12 state and 4 federally listed species. A total of 32 wetland-dependent species are breeding residents. The other 34 species depend on the Kissimmee River during some portion of their life cycle, particularly during migration and overwintering, while foraging, roosting, and seeking cover (**Appendix F**, Table F-5). Of the remaining 93 bird species, 68 are considered facultative and 25 opportunistic users of wetlands. Facultative users may nest, forage, and seek shelter in upland habitats, but preferentially use wetlands in most geographic areas or during particular times of the year (e.g., dry season). Opportunistic wetland users are species typically associated with uplands that may periodically take advantage of abundant food or habitat resources near water in certain locations along the Kissimmee River.

During aerial (helicopter) surveys, avian point counts, and other fieldwork, all wetland-associated bird species in **Appendix F**, Tables F-4 and F-5, have been documented using the floodplain in some capacity. The breeding status of each species along the river was derived from direct observations of nesting, presence during the breeding season, and the Florida Fish and Wildlife Conservation Commission (FWC) Breeding Bird Atlas, Distribution Maps by County (FWC 2003). If specific measurements of water depths were not provided in the literature (primarily from Poole [2008]), water depths were taken from direct observations made during point-count surveys or were estimated based on water depths associated with particular vegetation communities along the river. Habitat types were based on field observations made during point-count surveys or from descriptions in the literature that were translated to one of the three primary vegetation types found along the Kissimmee (Broadleaf Marsh, Wet Prairie, and Wet Shrub).

4.2.2.1 Habitat and Hydrologic Requirements of Wetland-Dependent Birds

The general hydrologic characteristics of foraging (mean water depth) and breeding (mean water depth under nest) habitat for wetland-dependent birds of the Kissimmee River are presented in **Appendix F**, Table F-5. Bird habitat along the Kissimmee River can be classified into four principal vegetation community types. The three dominant types of marsh vegetation are the Broadleaf Marsh, Wetland Shrub, and Wet Prairie groups, described in **Appendix F**. The fourth is Wetland Forest, which is described in Carnal and Bousquin (2005). The plant, macroinvertebrate, fish, amphibian, reptile, bird, and small mammal communities associated with these habitats form the basis of the food web for wading birds, waterfowl, shorebirds, marsh birds, and songbirds. The distribution and structure of these habitats are a function of the timing, magnitude, and duration of the annual hydrologic cycle of flooding (typically June to November) and drying (usually December to May). As such, these functions work in tandem to dictate the location, timing, and success of foraging and reproduction along the river. Wading birds throughout South Florida, for example, are thought to cue the timing of breeding to the increased availability of prey during the dry season, when aquatic invertebrates and small fish become concentrated in isolated pools as water levels recede (Frederick and Collopy 1989a). Without this natural flood/drought cycle, which along the Kissimmee River causes water levels to fluctuate an average of 5.8 ft per year, vegetative community composition, structure, and function change and can negatively impact wetland-dependent bird populations (Toth 1993, Weller 1995). Reduced water levels can affect nest site selection and increase vulnerability to land-based predators (Frederick and Collopy 1989b).

Of the 32 bird species that depend on wetlands for successful reproduction, 9 primarily use herbaceous marsh (i.e., Broadleaf Marsh and Wet Prairie) as their principal nesting habitat, while 23 primarily depend on woody wetland vegetation (i.e., Wetland Shrub and Wetland Forest) to serve as nesting substrate (**Appendix F**, Table F-5). However, four wetland nesting species (bald eagle [*Haliaeetus leucocephalus*], boat-tailed grackle [*Quiscalus major*], mottled duck [*Anas fulvigula*], and osprey [*Pandion haliaetus*]) can nest in upland habitats as long as they are in close proximity to water (e.g., <2 km for bald eagles).

Wading bird nesting colonies along the river typically are found in woody shrubs and trees, either submerged or surrounded by water. This is typical of many wading bird colonies throughout the state that form as follows:

1. On islands (5 to 25 acres [2 to 10 hectares]) surrounded by at least 1.6 ft (0.5 m) of water during the January to July breeding season in Florida (Frederick and Collopy 1989b, White et al. 2005)
2. >164 ft (>50 m) from uplands, or the "mainland" if an island
3. >328 ft (>100 m) from human disturbance
4. Within 0.25 miles (0.4 km) of suitable vegetation with dead and live nesting materials
5. Within 6.2 miles (10 km) of suitable foraging habitat (White et al. 2005)

The Florida sandhill crane (*Grus canadensis pratensis*) typically nests in shallow (5.3 to 12.8 inches [13.5 to 32.6 cm] deep) herbaceous wetlands composed of Broadleaf Marsh and Wet Prairie vegetation types (Stys 1997). Nesting sites may shift to more permanent waterbodies (e.g., lakes) when ephemeral wetlands dry too early in the nesting season or during longer-term drought conditions.

Two waterfowl species that consistently nest along the Kissimmee River are mottled ducks and wood ducks (*Aix sponsa*). Mottled ducks were reported to nest on the ground in hayfields, grazed pasture, and natural upland prairie habitat, averaging a distance of 453 ft (138 m) from water. Wood ducks are tree nesters that prefer mature forests with suitable cavity trees over or near water (<1.2 miles [<2 km]) (Poole 2008).

In addition to nesting habitat requirements, many species require contrasting habitat types to forage and provide food for their young. Of the 32 wetland obligates, 20 species will forage in all 4 vegetation communities in addition to open-water habitat; 5 species specialize in Broadleaf Marsh and/or Wet Prairie; 1 species specializes in Wetland Forest and/or Wetland Shrub; 3 species forage primarily in open water near Wetland Forest and Wetland Shrub; and 3 species forage in a mixture of habitats (**Appendix F**, Table F-5). Preferred habitats of the facultative and opportunistic species can be found in **Appendix F**.

Additional information about stage recession rates is available for wading birds in the Everglades based on long-term monitoring of nesting effort and water levels (Tarboton et al. 2004).

Snail kites (*Rostrhamus sociabilis*) build nests in flooded vegetation of either woody (e.g., willow [*Salix* spp.], buttonbush [*Cephalanthus occidentalis*], cypress [*Taxodium* spp.]) or non-woody (e.g., cattail [*Typha* spp.], bulrush [*Scirpus* spp.]) plant species (Snyder et al. 1989). Nests typically are close, i.e., <164 ft (<500 meters [m]), to appropriate foraging habitat, >164 ft (>50 m) away from the shoreline, and submerged or surrounded by water >1.6 ft (>0.5 m) deep during the January to July nesting season to serve as an effective barrier against land-based predators (e.g., raccoons [*Procyon lotor*]) (Sykes et al. 1995).

Snail kites are almost entirely dependent on both native and exotic apple snails (*Pomacea* spp.) for survival; therefore, snail kite foraging habitat must provide the life history requirements of apple snails, while allowing for successful visual foraging by snail kites. Female apple snails deposit eggs on emergent substrates approximately 3.5 to 9.8 inches (9 to 25 cm) above the water surface during peak egg cluster production in Central Florida (April to May) (Turner 1996, Darby et al. 1999). Darby et al. (2008) found native apple snail recruitment could be reduced during seasonal drydowns by two possible mechanisms: 1) reduced mating and egg-laying due to an early drydown before the peak egg-laying period, or 2) decreased survival of juveniles too small to survive a late season drydown after hatching. However, drydowns occurring every 2 to 3 years are deemed important for maintaining emergent aquatic vegetation critical for egg-laying and aerial respiration (Darby et al. 2008).

Although native apple snails in Florida are naturally adapted to water level fluctuations of 3 to 4 ft (0.9 to 1.2 m) per year, they need to migrate to deeper water during recession events or aestivate in bottom sediments to avoid stranding and desiccation. Darby et al. (2002) found that when water receded to a depth of <4 inches (<10 cm), native apple snails ceased all movements and became stranded in dry marsh. Thus, prolonged low water levels in wetlands can significantly reduce snail kite access to apple snails due to apple snail mortality, matting down of emergent vegetation and subsequent reduction in visibility of apple snails from above, or declines in recruitment during the following season. Complete drying out of the vegetated littoral zone of lakes or wetlands can eliminate snail kite foraging habitat temporarily (e.g., up to 3 months during the dry season) or permanently (e.g., as the result of drainage or other human disturbance). The former is considered part of the natural hydrologic regime in Central Florida. Darby and Percival (2000) indicated 75% of adult apple snails survive this period of exposure to drydown conditions, while 50% survived up to 4 months. Conversely, high water can negatively impact apple snails and their eggs by drowning egg clusters during rapid ascension events and submerging emergent vegetation so that it is unavailable for oviposition. In general, any large changes in water level (e.g., ≥6 inches [≥15 cm] within 2 to 3 weeks) during and after egg-laying can drown egg clusters during high water, cause adults to migrate out of the vegetated zone, or cause egg-laying vegetative substrate to collapse during rapid recession.

The incursion of exotic island apple snails (*Pomacea maculata*) into the LKB has improved foraging conditions for snail kites on the Kissimmee River floodplain, as the exotic apple snail breeds nearly year-round (allowing snail kites to nest well into the wet season) and may be more tolerant of drought. Snail kite activity on the floodplain has greatly increased since arrival of the exotic apple snail, with nearly 100 nests documented on the Kissimmee River floodplain in summer 2018, many of which successfully fledged young. However, as in lakes, nesting remains highly vulnerable to rapid changes in hydrology because rising water levels can inundate nests, while falling water levels can expose them to terrestrial predation. Foraging habitat for snail kites within the Kissimmee Basin includes shallow water (usually ≤4.3 ft [≤1.3 m]) that allows birds to forage effectively for native and exotic apple snails, their principal prey (Sykes et al. 1995). Snail kites fly low (5 to 33 ft [1.5 to 10 m]) over the water or still hunt from perches, while searching for apple snails within the top 6.3 inches (16 cm) of the water column (Sykes et al. 1995).

Wading birds will forage in small (<107 ft^2 [<10 m^2]), and large (>0.25 acres [>1,000 m^2]) habitat patches of all vegetation types, including open water, within wetlands and lake littoral zones. Wading birds usually forage within 3 to 12.5 miles (5 to 20 km) of a breeding colony site. As their collective name implies, wading birds forage by wading in shallow water (2 to 16 inches [5 to 40 cm]) that varies by the morphological characteristics of each species (especially leg length) (**Appendix F**, Table F-5). Although not part of the wading bird order Ciconiiformes, wading depths of the Florida sandhill crane (<12 inches [<30 cm]) also are limited by leg length (Stys 1997).

Fourteen species of ducks use the Kissimmee River, although only four species are resident breeders. Seven species are dabbling ducks that forage at or near the surface, four are diving ducks that forage much deeper under water, and three are tree ducks that perch and/or nest in trees. Dabbling duck foraging habitat along the Kissimmee River generally is shallow (2 to 12 inches [5 to 30 cm]) emergent wetlands with a vegetation:open water ratio between 30:70 and 70:30. Emergent vegetation should be interspersed among open-water areas, forming a mosaic of patches varying in size and shape. Dabbling duck habitat should be available year-round.

Diving duck foraging habitat along the Kissimmee River is typically 1 to 6 ft (30 to 180 cm) deep with at least half the area less than 4 ft (120 cm) in depth. Quality habitat usually has vegetation coverage of at least 40% submerged or floating-leaved vegetation and no more than 40% emergent vegetation. Typically, at least 30% of all vegetation within this habitat is composed of any combination of the following species: *Nymphaea odorata, Brasenia schreberi, Najas* spp., *Potamogeton* spp., *Vallisneria americana,* and *Hydrilla verticillata*. Submerged aquatic plant species need to reach the water surface for good habitat value. Diving duck habitat is needed from November 15 through March 15, when migrant diving ducks are most commonly found along the Kissimmee River.

4.2.4 KRRP and the Hydrologic Requirements of Fish and Wildlife

The importance of hydrologic characteristics (i.e., discharge, stage, depth, and velocity) as the key components of habitat in river-floodplain ecosystems is well-established in ecological literature (Poff et al. 1997, Arthington 2012). Thus, re-establishment of pre-channelization hydrologic characteristics is a cornerstone of the KRRP. Hydrologic characteristics necessary for the restoration of ecological integrity for fish and wildlife in the Kissimmee River were stated as five hydrologic criteria (**Box 1**) that have been used to guide the design of the restoration project (USACE 1991, Section 8.4.4, Restoration Criteria). These criteria are consistent with the hydrologic requirements for fish and wildlife as described earlier and in **Appendix F**.

The hydrologic criteria emphasize pre-channelization data and the importance of natural patterns of discharge and stage fluctuation in the river and floodplain, especially seasonal and annual variability. The natural pattern of rising and falling discharge with seasonal and annual variability has been termed the natural flow regime and is considered critical for the protection of fish and wildlife (Poff et al. 1997). In floodplain rivers like the Kissimmee River, flows that inundate portions of or all of the floodplain are termed a flood pulse. The resulting connectivity between the river channel and floodplain is a critical component of the habitat requirements of fish and wildlife populations (Junk et al. 1989).

The first hydrologic criterion emphasizes the importance of maintaining flow continuously through time with seasonal and annual variability of the pre-channelization system. This criterion reestablishes the natural flow regime for the Kissimmee River. The other four criteria ensure that as flow passes through the reconstructed river channel it produces desired outcomes for average velocity (second criterion) and floodplain inundation (third, fourth, and fifth criteria).

Box 1. Hydrologic Criteria for the Kissimmee River Restoration Project (From: USACE 1991).

Continuous flow with duration and variability characteristics comparable to the pre-channelization records – The most important features of this criterion are (a) reestablishment of continuous flow from July–October, (b) highest annual discharges in September–November and lowest flows in March–May, and (c) a wide range of stochastic discharge variability. These features should maintain favorable dissolved oxygen regimes during summer and fall months, provide non-disruptive flows for fish species during their spring reproductive period, and restore temporal and spatial aspects of river channel habitat heterogeneity.

Average flow velocities between 0.8 and 1.8 feet per second when flows are contained within channel banks – These velocities complement discharge criteria by protecting river biota from excessive flows, which could interfere with important biological functions (e.g., feeding and reproduction), and provide flows that will lead to maximum habitat availability.

A stage-discharge relationship that results in overbank flow along most of the floodplain when discharges exceed 1,400–2,000 cubic feet per second – This criterion reinforces velocity criteria and will reestablish important physical, chemical, and biological interactions between the river and floodplain.

Stage recession rates on the floodplain that typically do not exceed 1 foot per month – A slow stage recession rate is required to restore the diversity and functional utility of floodplain wetlands, foster sustained river/floodplain interactions, and maintain river water quality. Slow drainage is particularly important during biologically significant time periods, such as wading bird nesting months. Rapid recession rates (e.g., rates that will drain most of the floodplain in less than a week) have led to fish kills (i.e., during the Pool B Demonstration Project), and thus, are not conducive to ecosystem restoration.

Stage hydrographs that result in floodplain inundation frequencies comparable to pre-channelization hydroperiods, including seasonal and long-term variability characteristics – Ecologically, the most important features of stage criteria are water level fluctuations that lead to seasonal wet-dry cycles along the periphery of the floodplain, while the remainder of the (approximately 75%) of the floodplain is exposed to only intermittent drying periods that vary in timing, duration, and spatial extent.

A major component of the KRRP, the HRS is intended to help re-establish the natural flow regime from the Headwaters Revitalization Lakes to the Kissimmee River. The HRS will raise the regulation schedule for the Headwaters Revitalization Lakes so more water can be held in the lakes during periods of abundant rainfall and released at appropriate times to better mimic the natural pre-channelization flow regime than was allowed in the original design of the C&SF Project. The water held in this additional storage is essential for restoration of the natural flow regime.

A conceptual model is used to illustrate a single year of a discharge regime and the benefits to fish and wildlife associated with different portions of an annual flood pulse (**Figure 4-2**). The conceptual model begins with the peak of a flood pulse of sufficient magnitude to inundate the floodplain. Prior to channelization, peak flows could occur almost any time of year, depending on rainfall, but occurred most frequently at the end of the wet season or beginning of the dry season and continued well into the dry season (Anderson 2014a, Koebel et al. 2019). A flood pulse at that time of the year and extending well into dry season can provide floodplain habitat for foraging and reproduction by many fishes (especially the Off-channel Dependent Guild of fish), wading birds, waterfowl, and the endangered snail kite, which has begun nesting in the Kissimmee River floodplain.

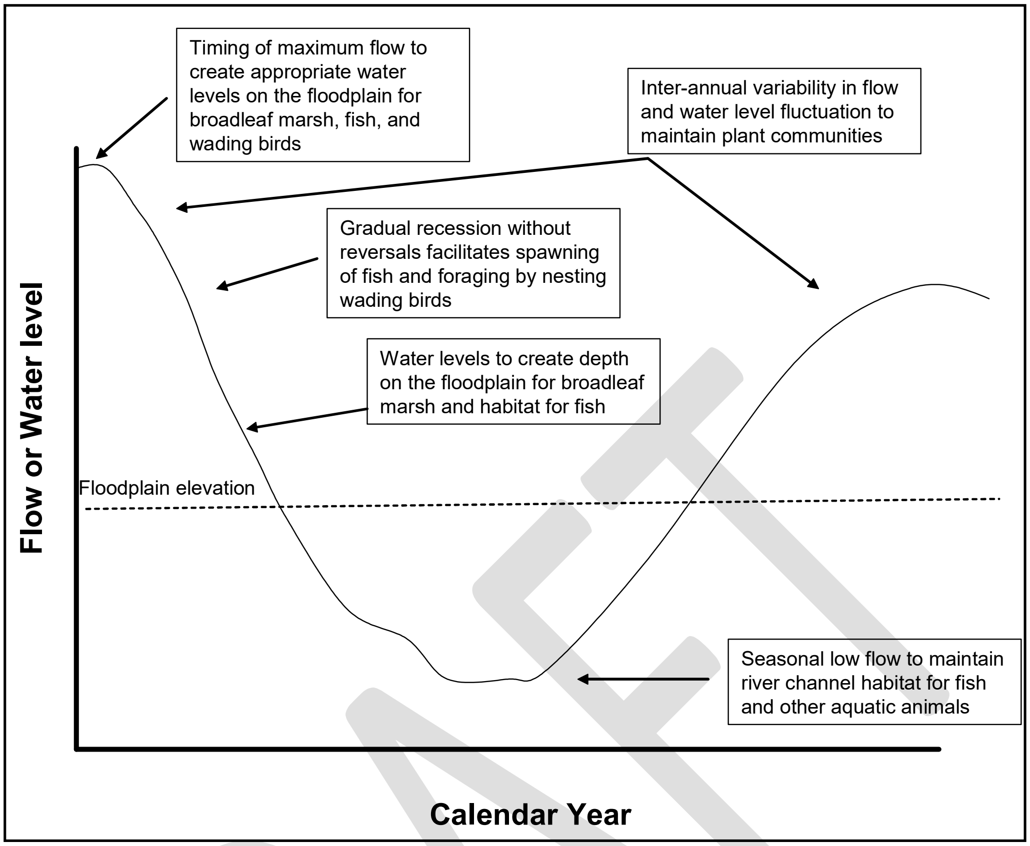


Figure 4-2. Relationship between fish/wildlife and flow or stage.

The peak of the flood pulse in the conceptual model is followed by a gradual recession extending the period of floodplain inundation and providing the appropriate water depth and duration at the frequency needed to maintain wetland plant communities. For example, Broadleaf Marsh, the predominant wetland vegetation group in the pre-channelization floodplain, requires hydroperiods with 1 ft of depth for 210 days in most years (Spencer and Bousquin 2014). Analysis of pre-channelization stage data shows that these conditions were met approximately two-thirds of years prior to channelization (Koebel et al. 2019). Extended periods of floodplain inundation with appropriate depth can protect nest sites and rookeries and also allow for the production of macroinvertebrates and small fish that are important prey species for wading birds and the endangered snail kite. Gradual recession rates also prevent trapping large numbers of fish and invertebrates on the floodplain and create favorable conditions for wading bird foraging. Large increases in flow during the gradual recession can disrupt spawning by fish and nesting by wading birds.

Gradual recession in the conceptual model ends with a transition to seasonal low flows. Such low flows should maintain sufficient depth to prevent crowding of fish and other aquatic animals. It also should have sufficient velocity to maintain habitat for fish and other aquatic animals by aerating the water and preventing accumulation of organic particles on the channel bed, which can benefit dissolved oxygen levels.

While the conceptual model does not explicitly address interannual variation, variability across years is important for long-term maintenance of habitat and persistence of fish and wildlife populations. River flow should vary from one year to the next as a result of rainfall variation and is necessary to maintain habitat characteristics, especially those of wetland plant communities and dependent fish and wildlife. For example, extreme high-water levels establish the upper elevation limit of wetland vegetation by limiting the growth of upland species; extreme low-water levels can create conditions that allow the seeds of some wetland plant species to germinate (Hill et al. 1998, Keddy and Fraser 2000).

4.3 Headwaters Revitalization Lakes and Upper Chain of Lakes Fish and Wildlife Resources

4.3.1 Fish and Wildlife Resources and Habitat

Wildlife considered during development of the Water Reservations include fish, amphibians and reptiles, birds, and mammals. The abundance of fish and wildlife is directly related to major wetland plant communities and their productivity, which form the foundation and structure of the fish and wildlife habitat associated with these waterbodies. The plant communities, in turn, are responsive to specific hydrology and generally are organized along shoreline depth gradients according to flooding tolerance. The KCOL and surrounding area support considerable fish and wildlife resources. The wildlife resources include a nationally recognized largemouth bass fishery, nesting colonies of the threatened wood stork (*Mycteria americana*) and endangered snail kite, and one of the largest concentrations of nesting bald eagles in the United States. Many of the same fish and wildlife species populate all seven of the KCOL reservation waterbodies due to the proximity of the lakes to each other and the canals that connect them.

4.3.1.1 Littoral Vegetation

Littoral vegetation is an important component of fish and wildlife habitat in lake ecosystems (e.g., Williams et al. 1985, Havens et al. 2005, Johnson et al. 2007). In lakes, vegetation is commonly distributed along an elevation gradient that corresponds to increasing light limitation with depth for submersed species and increasing hydroperiod for emergent species (Johnson et al. 2007). This section characterizes the vegetation communities present in each of the KCOL reservation waterbodies and the range of elevations where each occurs. Smaller lakes directly connected to the larger lakes are considered part of the reservation waterbody and are assumed to have similar ecological relationships with hydrology.

Plant communities associated with each of the KCOL reservation waterbodies have been classified from aerial imagery collected by the FWC between 2009 and 2016. The vegetation maps provide detailed estimates of the composition and distribution of flora in most of the reservation waterbodies. For descriptive purposes, the maps were reclassified into four major community types (**Table 4-1**) and overlaid onto approximate shoreline gradients of the reservation waterbodies. This summarizes years of mapping efforts to show how the distribution of littoral communities varies due to hydrologic variations between waterbodies.

Vegetation maps were developed using 2016 imagery for Lake Tohopekaliga and East Lake Tohopekaliga, while 2009 imagery was used for Lakes Hart-Mary Jane, Lakes Myrtle-Preston-Joel, the Alligator Chain of Lakes (represented by Alligator Lake), Lake Gentry, and two of the Headwaters Revitalization Lakes (Cypress and Hatchineha) (Mallison 2009, 2016). To determine elevation distributions for the four major community types (**Table 4-1**), vegetation maps were overlaid onto bathymetric maps developed from surveys in 2011 and 2012 and Osceola County's digital elevation model, which was derived from light detection and ranging (LiDAR) data collected by the United States Geological Survey in 2016. Bathymetric maps were used for lower elevations (a foot or more below maximum flood elevations) while the digital elevation model was used for the shallowest areas. There was no bathymetric map available for Lakes Kissimmee or Tiger, so only Cypress and Hatchineha were analyzed for Headwaters Revitalization Lakes vegetation patterns.

Table 4-1. Descriptions of the four major vegetation community types analyzed within the proposed reservation waterbodies for elevation distributions. Approximate hydroperiods are included for general reference.

Wetland Class	Description	Hydroperiod (days per year)
Shallow Marsh	Dominated by bunch grasses (*Axonopus furcatus, Spartina bakeri, Andropogon* spp., *Schizachyrium* spp., *Eragrostis* spp.), spikerushes (*Elocharis* spp.), beak rushes (*Rhynchospora* spp.), yellow-eyed grass (*Xyris ambigua*), smartweed (*Polygonum* spp.), American cupscale grass (*Sacciolepis striata*), and St. John's wort (*Hypericum* spp.)	0 to 365
Broadleaf Marsh	Includes pickerelweed and/or arrowhead (*Pontederia cordata*/*Sagittaria* spp.), and mixes of cattail (*Typha domingensis*)	300 to 365
Deepwater Grasses	Mixes or monocultures of maidencane (*Panicum hemitomon*), Egyptian paspalidium (*Paspalidium geminatum*), and bulrush (*Schoenoplectus californicus*) as well as mixes of cattail	365
Floating Leaf (Pads)	Mixes or monocultures of water lilies (*Nymphaea* spp.), spatterdock (*Nuphar advena*), and/or American lotus (*Nelumbo lutea*)	365

Elevation statistics were calculated for each vegetation polygon based on underlying elevation data. The interquartile ranges of those elevations were plotted by community type for each reservation waterbody, with respect to the elevations of the water regulation schedules (**Figure 4-3**). Historical stage data for each waterbody are described in **Section 4.3.2**. These evaluation methods demonstrate how hydrology varies between waterbodies, both in terms of elevation relative to their respective regulation schedules and their interannual variability.

The elevation distribution of community types varied by reservation waterbody because hydrology varies between the lake systems. However, conceptually, the community types occupied similar positions relative to the regulation schedules within each lake ecosystem. The upland edges of the littoral zones have shallow marshes (short-hydroperiod graminoid and herbaceous species), which also occur with various stands of wetland trees and shrubs (not classified here due to effects of shoreline development). At slightly lower elevations, under semi-permanent or permanent inundation but in relatively shallow water, Broadleaf Marsh vegetation like pickerelweed (*Pontederia cordata*) and arrowhead (*Sagittaria lancifolia*) is predominant. Under permanent inundation and in deeper water (i.e., water up to 6 ft [1.8 m] deep at full pool), floating leaf aquatics like water lilies (*Nymphaea* spp.) and spatterdock (*Nuphar advena*), and deepwater grasses like maidencane (*Panicum hemitomon*) and Egyptian paspalidium (*Paspalidium geminatum*) dominate.

Most of the lakes showed a similar pattern in terms of wetland class elevations, though a few distinctions were notable. Lake Tohopekaliga, for example, has had more extreme drawdowns for fisheries habitat management than any other waterbody in the KCOL, and the deepwater grasses community extended the farthest downslope as a result; more than 6 ft (1.8 m) lower in elevation than the regulation schedule maximum.

The upper elevation of the Broadleaf Marsh community was consistent across waterbodies, except for Lakes Hart-Mary Jane and Lake Gentry. For all other reservation waterbodies, the upper elevation of this wetland class coincided with the lower quartile (25th percentile) of the historical range of lake stages. The Broadleaf Marsh community may occur at deeper elevations in Lakes Hart-Mary Jane and Lake Gentry due to forested wetlands obscuring detection or competing at higher elevations (Lake Gentry), or if stable water levels have enabled floating mats of Broadleaf Marsh to develop farther downslope. Note that the interquartile range (a measure of water level variation) for Lakes Hart-Mary Jane is the narrowest among the reservation waterbodies, which tends to promote tussock formation.

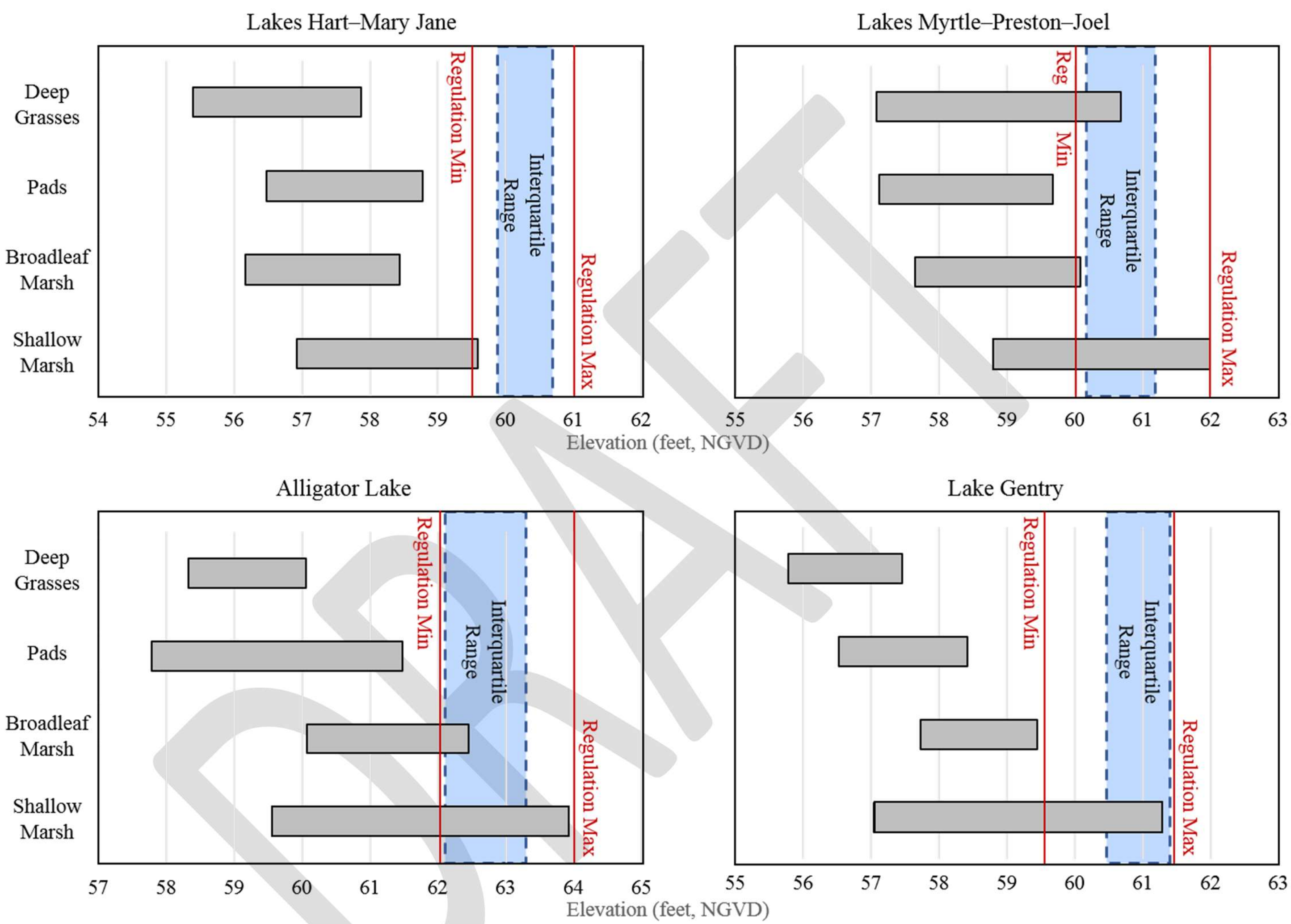


Figure 4-3. Approximate elevations of common vegetation community types for the proposed reservation waterbodies Lakes Hart-Mary Jane, Lakes Myrtle-Preston-Joel, Alligator Lake (representative of the Alligator Chain of Lakes), and Lake Gentry. Shaded gray bars represent the interquartile range of elevations for each community type, while the shaded blue box represents the interquartile range of the historical lake stages from Water Years 1972 to 2019. The minimum and maximum elevations of the regulation schedules are shown in red.

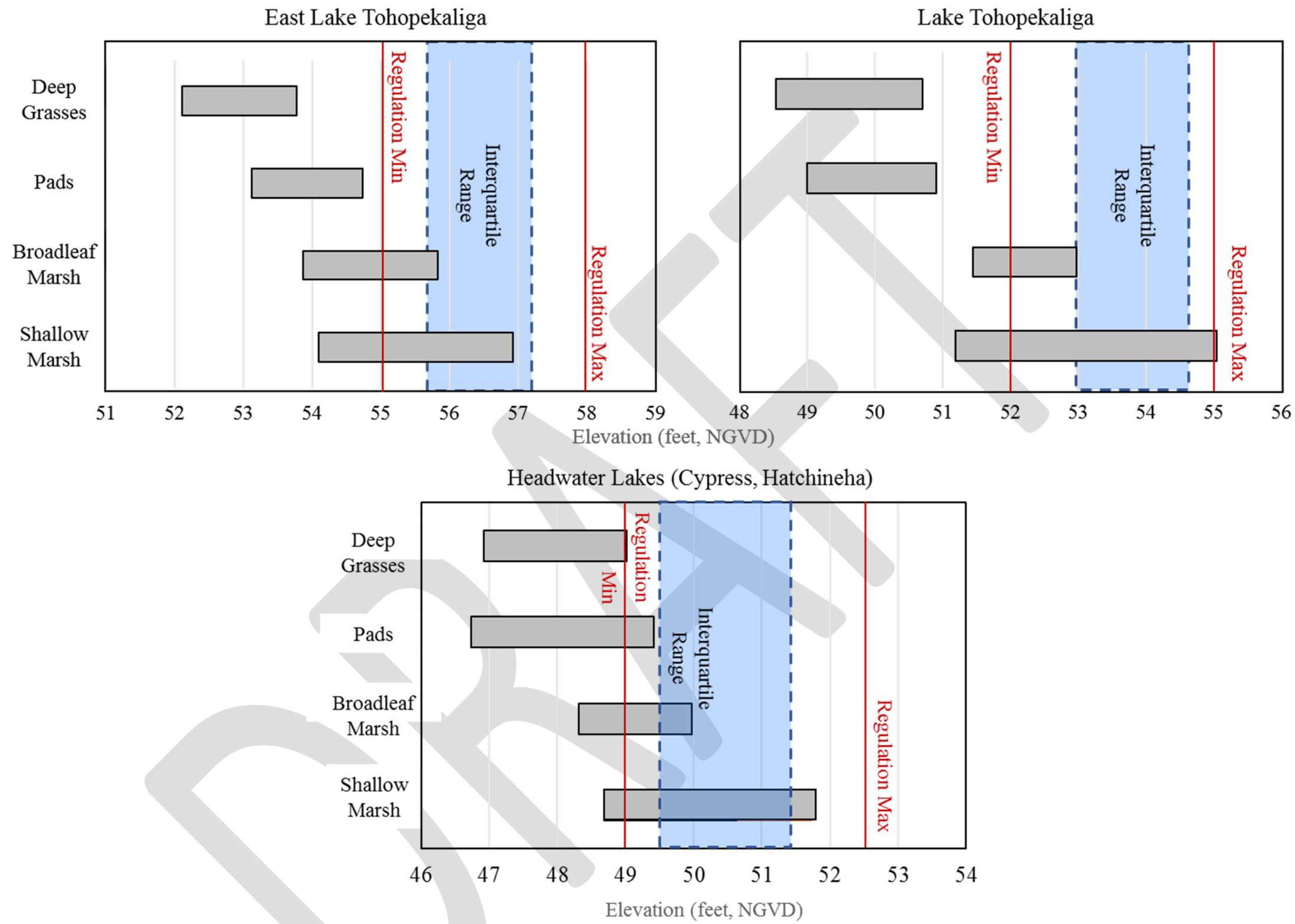


Figure 4-3 (cont.). Approximate elevations of common vegetation community types for the proposed reservation waterbodies East Lake Tohopekaliga, Lake Tohopekaliga, and the Headwaters Revitalization Lakes (Lakes Cypress and Hatchineha only; Lake Kissimmee bathymetry and Tiger Lake imagery/bathymetry were not available). Shaded gray bars represent the interquartile range of elevations for each community type, while the shaded blue box represents the interquartile range of the historical lake stages from Water Years 1972 to 2019. The minimum and maximum elevations of the regulation schedules are shown in red.

4.3.1.2 Fish and Wildlife

Fish are critical components of lake ecosystems, serving as links in the food chain between primary producers and higher consumers. Fish also provide a connection between the aquatic and terrestrial systems, serving as food for wading birds, ospreys, and bald eagles. Based on FWC sampling efforts in the 1980s (Moyer et al. 1987), the KCOL reservation waterbodies are home to at least 45 species of fish (**Table 4-2**). Four popular game fish species—black crappie (*Pomoxis nigromaculatus*), bluegill, largemouth bass, and redear sunfish—were collected in the six reservation waterbodies that were sampled. The littoral wetlands of the lakes are disproportionately important to the fishery, as these areas are the nurseries and prime locations of prey production in the waterbodies.

The KCOL fisheries are important economically as well as ecologically. The lakes are known worldwide for their prized sport fishing and support a robust recreation and tourism industry that is important to the local economy. In 2001, freshwater fishing in Florida generated an estimated economic impact of nearly \$2 billion (USFWS 2002). Because of the importance of their fisheries, the Headwaters Revitalization Lakes, Lake Tohopekaliga, and East Lake Tohopekaliga have been designated Fish Management Areas by the FWC, indicating the FWC is managing the freshwater fishery in cooperation with the local county (Osceola County).

Table 4-2. Fish species in six of seven proposed reservation waterbodies (Summarized from: Moyer et al. 1987).

Common Name	Species	Lakes Hart-Mary Jane	Headwaters Revitalization Lakes	East Lake Tohopekaliga	Lake Tohopekaliga	Alligator Chain of Lakes	Lake Gentry
Atlantic needlefish	*Strongylura marina*	X	X	X	X	X	X
Banded topminnow	*Fundulus auroguttatus*		X				
Black crappie	*Pomoxis nigromaculatus*	X	X	X	X	X	X
Blue tilapia	*Oreochromis aureus*		X	X	X		
Bluefin killifish	*Lucania goodei*	X	X	X	X	X	X
Bluegill	*Lepomis macrochirus*	X	X	X	X	X	X
Bluespotted sunfish	*Enneacanthus gloriosus*	X	X	X	X	X	X
Bowfin	*Amia calva*	X	X	X	X	X	X
Brook silverside	*Lebidesthes sicculus*	X	X	X	X	X	X
Brown bullhead	*Ameiurus nebulosus*	X	X	X	X	X	X
Brown hoplo	*Hoplosternum littorale*		X		X		
Chain pickerel	*Esox niger*	X	X	X	X	X	X
Channel catfish	*Ictalurus punctatus*	X	X	X	X	X	X
Coastal shiner	*Notropis petersoni*	X	X		X		
Dollar sunfish	*Lepomis marginatus*	X	X	X	X	X	X
Eastern mosquitofish	*Gambusia holbrooki*	X	X	X	X	X	X
Everglades pygmy sunfish	*Elassoma evergladei*	X	X	X	X	X	X
Flagfish	*Jordanella floridae*	X	X	X	X	X	X

Common Name	Species	Lakes Hart-Mary Jane	Headwaters Revitalization Lakes	East Lake Tohopekaliga	Lake Tohopekaliga	Alligator Chain of Lakes	Lake Gentry
Florida gar	*Lepisosteus platyrhincus*	X	X	X	X	X	X
Gizzard shad	*Dorosoma cepedianum*	X	X	X	X	X	X
Golden shiner	*Notemigonus crysoleucas*	X	X	X	X	X	X
Golden topminnow	*Fundulus chrysotus*	X	X	X	X	X	X
Inland silverside	*Menidia beryllina*		X	X			
Lake chubsucker	*Erimyzon sucetta*	X	X	X	X	X	X
Largemouth bass	*Micropterus salmoides*	X	X	X	X	X	X
Least killifish	*Heterandria formosa*	X	X	X	X	X	X
Longnose gar	*Lepisosteus osseus*	X	X	X	X	X	X
Okefenokee pygmy sunfish	*Elassoma okefenokoee*		X				
Pirate Perch	*Aphredoderus sayanus*	X	X	X	X	X	
Pugnose minnow	*Opsopoeodus emiliae*		X	X	X	X	X
Pygmy killifish	*Leptolucania ommata*	X				X	
Redear sunfish	*Lepomis microlophus*	X	X	X	X	X	X
Redfin pickerel	*Esox americanus americanus*	X		X		X	X
Sailfin catfish	*Pterygoplichthys disjunctus*		X				
Sailfin molly	*Poecilia latipinna*		X	X	X	X	X
Seminole killifish	*Fundulus seminolis*		X	X	X	X	X
Spotted sunfish	*Lepomis punctatus*	X	X	X	X	X	
Starhead topminnow	*Fundulus notti*	X		X		X	X
Swamp darter	*Etheostoma fusiforme*	X	X	X	X	X	X
Tadpole madtom	*Noturus gyrinus*		X		X	X	X
Tailight shiner	*Notropis maculatus*		X	X	X	X	X
Threadfin shad	*Dorosoma petenense*		X	X	X	X	
Warmouth	*Lepomis gulosus*	X	X	X	X	X	X
White catfish	*Ameiurus catus*	X	X		X		X
Yellow bullhead	*Ameiurus natalis*	X	X	X	X	X	X
Total Number of Species		**33**	**42**	**37**	**38**	**37**	**34**

Amphibians and reptiles (herpetofauna) are common but mostly inconspicuous inhabitants of lakes, ponds, streams, wet prairies, marshes and other aquatic habitats of Central Florida. While not extensively monitored in the KCOL reservation waterbodies, amphibians and reptiles likely occur throughout the waterbodies, especially in association with littoral wetland vegetation. A list of amphibian and reptile species likely to occur in the KCOL (**Table 4-3**) was compiled from regional distribution maps (Tennant

1997, Bartlett and Bartlett 1999) and a study of amphibian and reptile use of littoral wetlands on Lake Tohopekaliga (Muench 2004). The listed amphibians include frogs (seven species), one toad species, and six species of salamander. The reptiles include the American alligator (*Alligator mississippiensis*), eight species of turtles, and ten species of snakes. The American alligator is an economically important species and is federally listed as a threatened species (FWC 2013). Recreational harvesting of alligators is allowed with a permit in all the reservation waterbodies with public access, and the larger waterbodies support commercial harvesting of eggs. Lakes Kissimmee, Tohopekaliga, and Hatchineha have the largest alligator populations in the KCOL (Koebel et al. 2016).

Table 4-3. Aquatic amphibians and reptiles likely to occur in the Kissimmee Chain of Lakes. Taxa in bold are known to occur in the littoral zone of Lake Tohopekaliga (From: Muench 2004).

Common Name	Species
Amphibians	
Florida cricket frog	*Acris gryllus dorsalis*
Green tree frog	*Hyla cinerea*
Florida chorus frog	*Pseudacris nigrita verrucosa*
Little grass frog	*Pseudacris ocularis*
Eastern narrow-mouthed toad	*Gastrophryne carolinensis*
Bullfrog	*Rana catesbeina*
Pig frog	***Rana grylio***
Southern leopard frog	***Rana sphenocephala utricularia***
Two-toed amphiuma	***Amphiuma means***
Dwarf salamander	*Eurycea quadridigitata*
Peninsular newt	*Notophthalmus viridescens piaropicola*
Narrow-striped dwarf siren	*Pseudobranchus axanthus axanthus*
Eastern lesser siren	*Siren intermedia intermedia*
Greater siren	***Siren lacertina***
Reptiles	
American alligator	*Alligator mississippiensis*
Florida snapping turtle	***Chelydra serpentine osceola***
Florida chicken turtle	*Deirochelys reticularia chrysea*
Peninsular cooter	***Pseudemys floridana peninsularis***
Florida red-bellied turtle	*Pseudemys nelsoni*
Striped mud turtle	***Kinosternon baurii***
Florida mud turtle	*Kinosternon subrubrum steindachneri*
Common musk turtle	***Sternothernus odoratus***
Florida softshelled turtle	***Trionyx ferox***
Eastern garter snake	*Thamnophis sirtalis sirtalis*
Peninsula ribbon snake	*Thamnophis sauritus sackenii*
Florida water snake	***Nerodia fasciata pictiventris***
Florida green water snake	***Nerodia floridana***
Brown water snake	*Nerodia taxispilota*
Striped crayfish snake	***Regina alleni***
Eastern mud snake	***Farancia abacura abacura***
North Florida swamp snake	***Seminatrix pygaea pygaea***
Florida kingsnake	*Lampropeltis getula floridana*
Florida cottonmouth	*Agkistrodon piscivorus conanti*

Many birds are associated with lakes in Central Florida (e.g., Hoyer and Canfield 1990, 1994) and use these waterbodies for foraging, roosting, and reproduction. Audubon of Florida's list of Important Bird Areas includes three lakes within the KCOL: Lakes Kissimmee, Tohopekaliga, and Mary Jane (Pranty 2002). The Important Bird Area designation indicates that a site supports significant populations or diversity of native birds. An indication of the number of bird species using the KCOL reservation waterbodies can be obtained from Florida's Breeding Bird Atlas (FWC 2003), which was used to compile a list for lakes in Orange, Osceola, and Polk counties (**Table 4-4**). This list contains 43 bird species, and 29 of them were recorded in all 3 counties.

The snail kite is an endangered raptor whose distribution in the United States is restricted to Central and South Florida. Primary critical habitat for snail kites is listed as portions of the Everglades and Lake Okeechobee (USFWS 1999), though the KCOL region has become critically important to the population since 2005 (Cattau et al. 2012). During regional drought years when typical southern, palustrine habitats dry out, lacustrine habitats in the northern portion of the range play a crucial role in sustaining the population. The three primary waterbodies in the KCOL that snail kites use are East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee. However, snail kites recently began using portions of the restored Kissimmee River floodplain heavily during the non-breeding season, though some nesting has occurred there as well.

The Florida sandhill crane is listed as a threatened species by the State of Florida (FWC 2013). Its threatened status is based on low numbers due to a low reproductive rate, specialized habitat requirements, and loss of habitat due to humans (Williams 1978). Sandhill cranes occur throughout the KCOL and are included on the species lists in Three Lakes Wildlife Management Area and Lake Kissimmee State Park. While sandhill cranes typically nest in isolated wetlands, there are increasing reports of this species using urbanized and other developed areas (Toland 1999). Sandhill cranes nest in the marsh community on several of the KCOL reservation waterbodies, including Lakes Hart-Mary Jane, East Lake Tohopekaliga, Lake Tohopekaliga, and the Headwaters Revitalization Lakes (Welch 2004). Sandhill cranes likely are using the same habitat in other reservation waterbodies, although the extent of probable use is unknown.

The bald eagle population has been recovering throughout the United States since it was first listed as endangered in 1978. Its status was changed in 1995 to threatened, and it was delisted in 2007. Osceola and Polk counties have the highest number of bald eagle territories (225 total) in the state (FWC 2008). While not all of these territories are near the reservation waterbodies, 2007 nesting data had nests within a 2-km buffer of six reservation waterbodies. Only Lakes Myrtle-Preston-Joel had no nests reported, which could be due to a lack of access and recreational use of those lakes.

Four species of mammals in the region—marsh rice rat (*Oryzomys palustris*), marsh rabbit (*Sylvilagus palustris*), round-tailed muskrat (*Neofiber alleni*), and river otter *(Lutra Canadensis*)—are known to use wetland habitat within the KCOL (Florida Department of Environmental Protection 1998). In addition, several other species of mammals were observed using spoil islands created in the littoral zone of Lake Jackson, a contributing waterbody, including white-tailed deer (*Odocoileus virginianus*), wild pig (*Sus scrofa*), gray fox (*Urocyon cinereoargentus*), raccoon, and bobcat (*Felis rufus*) (Hulon et al. 1998). The extent to which these mammals use the littoral zones of the above lakes likely depends on the quality and quantity of upland habitat along the shores.

Table 4-4. Breeding birds associated with proposed lake reservation waterbodies (Summarized from: FWC 2003).

Common Name	County		
	Orange	Osceola	Polk
American coot	X	X	X
Bald eagle	X	X	X
Belted kingfisher			X
Black rail	X		
Black swan	X		X
Black-bellied whistling-duck			X
Black-crowned night heron	X	X	X
Black-necked stilt	X	X	X
Blue-winged teal	X		
Common moorhen	X	X	X
Double-crested cormorant	X	X	X
Fulvous whistling-duck	X	X	
Glossy ibis			X
Great blue heron	X	X	X
Great egret	X	X	X
Green heron	X	X	X
Gull-billed tern			X
Killdeer	X	X	X
King rail	X	X	X
Least bittern	X	X	X
Least tern	X		X
Limpkin	X	X	X
Little blue heron	X	X	X
Louisiana waterthrush	X		
Mallard	X	X	X
Mottled duck	X	X	X
Muscovy duck	X	X	X
Mute swan			X
Osprey	X	X	X
Pied-billed grebe	X	X	X
Purple gallinule	X	X	X
Red-winged blackbird	X	X	X
Ruddy duck			X
Sandhill crane	X	X	X
Short-tailed hawk	X	X	X
Snail kite		X	X
Snowy egret	X	X	X
Swallow-tailed kite	X	X	X
Tricolored heron	X	X	X
White ibis	X	X	X
Wood duck	X	X	X
Wood stork	X	X	X
Yellow-crowned night heron			X
Total	**35**	**31**	**39**

4.3.2 Hydrologic Characteristics

Major hydrological changes in the KCOL began in the 1880s when extensive canals were dredged to create a navigable route from Fort Myers to the town of Kissimmee, including the Kissimmee River and Chain of Lakes. Lake stages fell significantly and tens of thousands of acres of surrounding wetlands were drained. Between 1962 and 1969, the USACE implemented the C&SF Project for flood control, water supply, and environmental protection. Water control structures were built at the outlet of each waterbody and these lakes currently are operated using water control manuals and regulation schedules. These operations narrowed the range of water level fluctuation in the lakes by not allowing stages to rise as high or to fall as low as they had before regulation (**Figure 4-4**). Elimination of the higher water levels reduced the amount of wetland habitat for fish and wildlife. For example, an estimated 5,600 acres (2,266 hectares) of habitat for waterfowl were lost due to regulation of water levels in Lakes Kissimmee, Cypress, Hatchineha, and Tohopekaliga (Perrin et al. 1982).

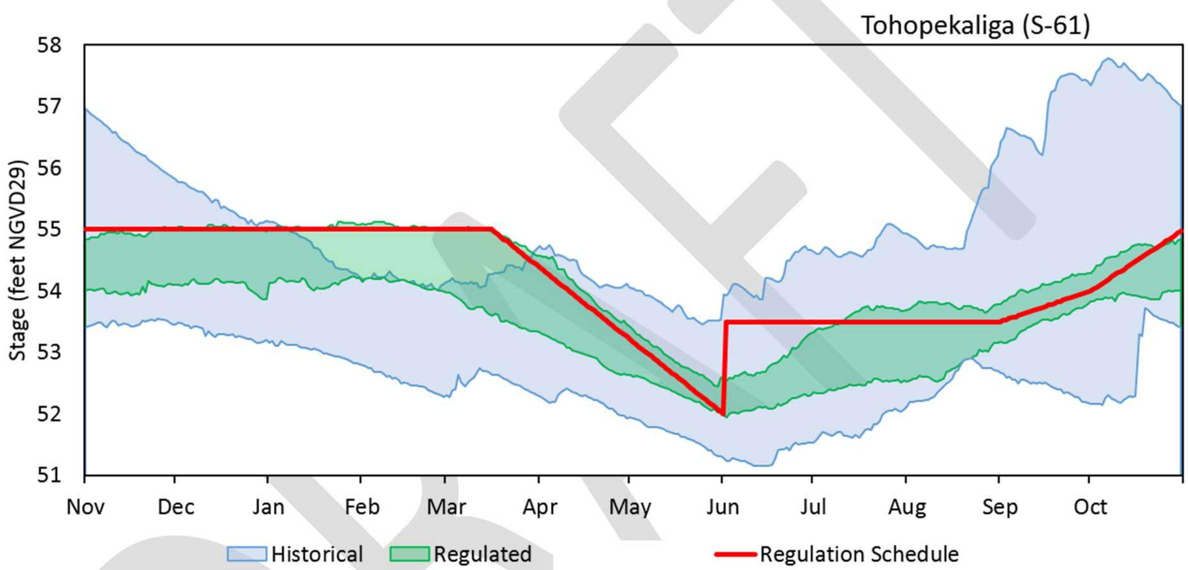


Figure 4-4. The interquartile ranges (25th to 75th percentiles) of daily lake stages before (blue, 1942 to 1962) and with (green, 1964 to 2019) regulation for Lake Tohopekaliga. The current regulation schedule is overlaid in red.

Compared to the major changes associated with adoption of regulation schedules, there have been relatively small adjustments to the schedules since they were first implemented. These changes include permanently shifting the range of water levels down 0.5 ft in Lake Gentry, raising the highest elevation 1 ft and lowering the minimum elevation 0.5 ft in East Lake Tohopekaliga and Lake Tohopekaliga, and raising the minimum elevation 0.5 ft in Lakes Hart and Mary Jane. Most of these schedule changes were made in 1975. In addition to changes in the minimum and maximum elevations in the schedules, minor changes in the shape (seasonality) of the schedule lines also have occurred. The current schedules have been in use since the early 1980s, but the general highs, lows, and seasonality of the schedules have remained relatively unchanged since the 1970s.

While the seasonality and shape of the regulation schedules are very similar among most of the reservation waterbodies (except Lakes Myrtle-Preston-Joel, which recedes from a maximum in December instead of March), the actual historical hydrologic patterns during the regulated period vary considerably among the systems. A review of historical stages from May 1971 through April 2019 (Water Years 1972 through 2019) for each waterbody showed the difference between median daily values and corresponding regulation schedules varies by season and by system (**Figure 4-5**). For example, median daily stages in East Lake Tohopekaliga and the Alligator Chain of Lakes often were approximately 0.75 ft below the regulation schedules during portions of the dry season (November to May), while Lakes Myrtle-Preston-Joel and Lake Gentry had less than 0.25 ft difference. These hydrologic differences affect the distribution and composition of littoral communities along lakeshore gradients (Keddy 2000, Wilcox and Nichols 2008) and the fish and wildlife associated with each. Drier lakes (relative to their regulation schedules), such as the Alligator Chain of Lakes and East Lake Tohopekaliga, likely have shorter-hydroperiod vegetation communities farther downslope from the maximum flood elevation, whereas Lake Gentry may have relatively long-hydroperiod communities farther upslope.

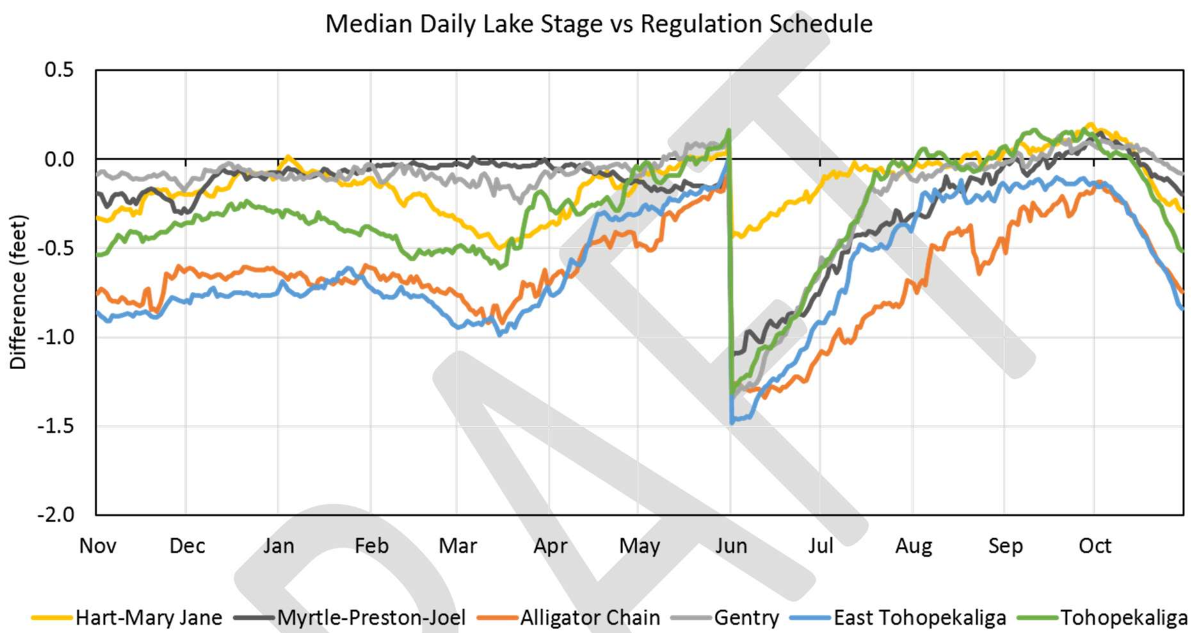


Figure 4-5. The difference between median daily lake stages (May 1972 to April 2019) and each reservation waterbody's current regulation schedule. Negative values indicate median stages are lower than the regulation schedule at that time of year.

The Headwaters Revitalization Lakes were subject to the same effects from water control structures and subsequent regulation schedules but have undergone more recent operational changes. **Section 4.1** discusses regulation of the Headwaters Revitalization Lakes (S-65) under an interim regulation schedule, which was implemented after the first phase of construction for the KRRP was completed in 2001. The HRS will be implemented when KRRP construction is completed.

4.3.3 Linkages Between Hydrology and Biology

Fish and wildlife in the reservation waterbodies have been linked to seasonal and annual patterns of water level fluctuation that support wetland plant communities (USFWS 1958, Williams et al. 1985, Johnson et al. 2007). These vegetation zones are important locations for food production. Parts of plants, such as seeds and tubers, can be consumed directly. Plants also provide attachment sites for algae and invertebrates, which are eaten by various species of fish and wildlife. Additionally, plants provide shelter from predators and serve as nesting sites for many species.

Fluctuating water levels are one of the most important factors that determine the type, abundance, and distribution of vegetation in lake littoral zones (Hill et al. 1998, Keddy 2000, Keddy and Fraser 2000). These fluctuations are important on seasonal, annual, and interannual scales. For example, infrequent, extreme low water levels allow organic components of exposed sediments to decompose more rapidly (Cooke et al. 1993) and allow the seeds of some wetland plants to germinate (Hill et al. 1998, Keddy and Fraser 2000). Extreme low water levels also are an important determinant of the lower limit of emergent vegetation in the KCOL reservation waterbodies (Holcomb and Wegener 1972).

In the KCOL, habitat use by fish and wildlife is linked to seasonal and annual patterns of water level fluctuation. This is due, in part, to how hydrology determines zonation of wetland plant communities, which in turn provide food, shelter, and breeding habitat for various faunal communities. Seasonal elevation of water level also gives fish access to littoral marsh and other vegetated areas where they spawn. During wet years, higher lake stages in the spring increase the percentage of the littoral zone that remains flooded, thereby increasing the availability of foraging and breeding habitat for fish and other aquatic fauna.

Fluctuating water levels are needed to create appropriate inundation patterns (hydroperiods) to maintain the wetland plant communities that provide shelter, serve as spawning locations, and provide refuge for prey. In the KCOL reservation waterbodies, fish use Broadleaf Marsh, Floating Leaf, Deepwater Grasses, and even the Shallow Marsh community when lake stages are sufficiently high. These plant communities are distributed along water depth gradients, and lake stage affects the quantity and quality of available habitats. High water levels during the spawning season, for example, provide fish access to shallower, sandy areas with more vegetative cover for eggs and fry.

Fish are completely dependent on the hydrologic patterns that inundate habitats, provide oxygen, and shape the composition and distribution of vegetation on the lakes. Current regulation schedules for the reservation waterbodies approximate some aspects of natural lake hydrology (e.g., seasonal high at the end of the wet season and a seasonal low at the end of the dry season), albeit with artificial durations. Most regulation schedules permit maximum water levels throughout the winter and early spring. Although such stable, high lake stages would be somewhat unnatural throughout the first portion of the dry season, they do allow fish seasonal access to upper lake elevations for breeding and recruitment, which is important given most of the lakes are reduced in size from their historical condition. Seasonally low water levels are beneficial for predators because littoral shelter becomes limited and forage fish are concentrated. This is especially true for adult largemouth bass that wait at the fringes of littoral vegetation to ambush prey.

Most of the amphibians and reptiles likely to be associated with the KCOL reservation waterbodies prefer vegetated (often dense), shallow littoral zones of lakes and are likely to be associated with the Shallow Marsh, Broadleaf Marsh, and Floating Leaf plant communities of these lakes. A hydrologic regime that offers protection of these three plant communities likely will provide protection for most amphibians and reptiles. Decreasing hydroperiods or eliminating littoral zone habitats by artificially reducing lake stages would adversely impact amphibian and reptile communities of these lakes.

Of the amphibians and reptiles, the feeding and nesting hydrologic requirements are best understood for the American alligator. Alligators are opportunistic and feed on a variety of prey (Newsom et al. 1987). In north-central Florida, alligators feed on fish, reptiles, amphibians, birds, mammals (e.g., round-tailed muskrat), and invertebrates (e.g., crayfish, freshwater snails) (Delany and Abercrombie 1986). Juvenile alligators consume more invertebrate prey than do adults (Delany and Abercrombie 1986, Delany 1990). Nesting in the KCOL is associated with the Broadleaf Marsh vegetation community. Alligators push together soil and vegetation to build dome-shaped nesting mounds, often near permanent water. When constructing nests, alligators show no preference for sites or specific plant species (Goodwin and Marion 1978) but need dense marsh vegetation for nesting material.

Alligators require a hydrologic regime that maintains marsh habitat and provides inundation during the nesting season, and extreme high or low water levels can reduce the availability of nesting sites (Johnson et al. 2007). Nesting generally occurs from mid-June to mid-September, and it is important that water levels are high enough during this period to inundate the marsh community so female alligators can construct nests that will be protected from raccoons and other terrestrial predators (Goodwin and Marion 1978, Newsom et al. 1987, Johnson et al. 2007). It also is important that water levels do not rise so rapidly that nests and eggs are flooded, which might occur after several days of heavy rainfall (Goodwin and Marion 1978).

Extreme water levels can affect alligator survival. Hatchlings use dense marsh habitats to avoid predators and lower water levels may force them into deeper, less protected areas of the marsh (Woodward et al. 1987). Low water levels can also cause heat stress and concentrate alligator populations, making them more vulnerable to cannibalism, disease, and prey limitations (Woodward et al. 1987).

There are specific hydrologic requirements for wading birds and their colonies, and for imperiled avian species in the region. Wading bird colonies depend on water depths in wetland and marsh communities that are shallow enough for foraging, deep enough for protection of nests, and support marsh plant communities long term. Water depths should be at least 1.6 ft (0.5 m) deep around nesting colonies throughout most of the nesting season to reduce terrestrial predator access (Frederick and Collopy 1989b, White et al. 2005). Water levels also must be shallow enough that individuals can hunt for prey and should gradually recede throughout the dry season to concentrate prey.

The hydrologic requirements of snail kites relate to the availability of suitable nesting habitat and their principal prey, apple snails. Snail kites nest in low vegetation over water and are susceptible to failure if water levels recede or ascend too quickly during the breeding season, especially during the peak months from March to June. Additionally, water levels that begin receding too early in the breeding season (prior to January) may reduce the amount of inundated breeding and foraging habitat available during peak nesting periods. Therefore, providing adequate snail kite habitat during the dry season in the KCOL requires balancing high enough water levels to maximize inundated habitat while still allowing for moderate recession rates until June.

Snail kites require sufficient water levels during the nesting season to provide a barrier to terrestrial predators around their nests. A depth of 1 ft (0.3 m) at the beginning of nesting with a slow recession rate is the minimum depth needed to protect nests (Sykes et al. 1995) but will vary depending on distance to shore or density of vegetation between the nest and shore.

The Florida apple snail (*Pomacea paludosa*), which was the primary prey source of snail kites before the proliferation of the exotic apple snail (*Pomacea maculata*), also has specific hydrologic requirements. This species has a life span of a little more than 1 year. Populations of apple snails depend on strong recruitment from eggs laid above water on emergent vegetation or other appropriate substrates. While eggs can be laid from February to November, the peak egg-laying period is April to May, when water levels are declining (Darby et al. 2008). Rapidly declining water levels can leave newly hatched apple snails exposed to desiccation. Apple snails occur in association with emergent vegetation found in the Shallow Marsh, Broadleaf Marsh, and Deepwater Grasses plant communities. Apple snails have poor dispersal ability and are susceptible to desiccation when surface water disappears. Therefore, water levels that completely drain these communities can cause mortality of apple snails.

The hydrologic requirements of sandhill cranes relate primarily to nesting requirements. Nests are constructed in emergent marshes. Nest initiation can begin as early as December, but usually does not begin until January and can extend through August (Stys 1997). In south-central Florida, average laying dates are from February 22 to 24 (Walkinshaw 1982); the mean laying date is March 3 (Tacha et al. 1992). The average water depth at sandhill crane nests was 0.97 ft (29.6 cm) at the beginning of nesting season in Central Florida (Walkinshaw 1982). Most production of sandhill cranes in Osceola County (Three Lakes Wildlife Management Area) occurred in years with average or above average water levels during the nesting and post-nesting season (Bennett 1992).

The hydrologic requirements of bald eagles include nesting and foraging habitat. Throughout Florida, most bald eagle nests are in pine trees (*Pinus palustris* and *Pinus elliottii*) (FWC 2008), but in the KCOL, they are primarily located in oaks (*Quercus* spp.) and cypress (*Taxodium* spp.). The lakes are much more important for foraging habitat than nesting habitat. Bald eagle nests typically are within 1.25 miles (2 km) of waterbodies with suitable foraging habitats (Buehler 2000). In north-central Florida, bald eagles feed predominantly on fish, waterfowl, mammals, and reptiles (McEwan and Hirth 1980). During the nesting season, bald eagles prefer large fish (13.4 to 15 inches [34 to 38 cm]) (Buehler 2000). Fish that forage near the surface or that occur in shallow water near shore often are taken by bald eagles. A hydrologic regime that supports prey populations is critical to meet the needs of bald eagles.

CHAPTER 5: METHODS AND ANALYSES USED TO IDENTIFY RESERVED WATER

5.1 Introduction

This section summarizes the approaches taken to identify the water that should be reserved from allocation to protect fish and wildlife in each of the proposed reservation waterbodies. The standards on which Water Reservation rules are based [Section 373.223(4), F.S.] afford the SFWMD Governing Board considerable discretion and judgment in determining the quantities and timing of waters that may be reserved from use for the protection of fish and wildlife or public health and safety. The identification of water proposed for reservation is first discussed for the Kissimmee River and Headwaters Revitalization Lakes reservation waterbodies, followed by the UCOL waterbodies.

5.2 Rationale for Reserving All Surface Water Kissimmee River and Headwaters Revitalization Lakes

The KRRP was developed to address public concerns about the effects of the C&SF Project on the Kissimmee River, specifically that loss of flow and floodplain inundation in the Kissimmee River and floodplain had resulted in significant loss of wetland and aquatic habitat and reduced populations of many species of fish and wildlife. The SFWMD, USACE, and other state and federal agencies collaborated through a long period of planning that included a demonstration project, experimentation, a physical model, and computer modeling. The recommended KRRP plan was described in the report *Central and Southern Florida Project Final Integrated Feasibility Report and Environmental Impact Statement Environmental Restoration Kissimmee River, Florida* (USACE 1991) and was authorized by the United States Congress in the Water Resource Development Act of 1992. The estimated final cost of the KRRP is approximately $800 million.

The Headwaters Revitalization Schedule (HRS) was developed to provide the flows from S-65 needed to meet the ecological integrity goal of the KRRP to protect fish and wildlife and help re-establish pre-regulation populations. An interagency team (USACE, SFWMD, USFWS, and FWC) conducted analyses that considered 21 alternative schedules, as described in USACE (1996). After extensive analysis and completion of an environmental impact statement pursuant to the National Environmental Protection Act, the USACE adopted the HRS in 1996. The schedule will be implemented when KRRP construction is complete, which currently is projected for December 2020.

The HRS creates storage in the Headwaters Revitalization Lakes reservation waterbodies by allowing water levels to rise higher than the previous schedule. This allows water to accumulate in the reservation waterbodies during wetter seasons/years to be discharged at a rate that meets the KRRP's hydrologic and ecological integrity goals, which protect fish and wildlife as well as their habitats. Thus, the HRS ensures water levels in the Headwaters Revitalization Lakes reservation waterbodies support fish and wildlife while also meeting the downstream goals of the KRRP.

During development of the HRS, 21 alternatives were simulated using the UKISS model (Fan 1986) to estimate each alternative's effects on the hydrology of the Kissimmee River and Headwaters Revitalization Lakes. Ultimately, an alternative that fully met KRRP and Headwaters Revitalization Lakes project objectives was not found among the simulations (USACE 1996). However, the best-performing alternative, called RS9D, was endorsed and selected by the team agencies (USACE 1996) as the tentatively selected plan (now simply HRS). Because the 1996 simulations could not fully meet KRRP goals, SFWMD scientists concluded that the 1996 analysis supported the reservation of all water not already allocated from the Kissimmee River and Headwaters Revitalization Lakes reservation waterbodies (**Appendix A**, Figures A-8 and A-9) to ensure protection of fish, wildlife, and habitat intended to benefit from the KRRP.

This conclusion was supported by modeling done specifically for the Kissimmee River and Chain of Lakes Water Reservations in 2008 (SFWMD 2009). The SFWMD developed the Alternative Formulation and Evaluation Tool – Water Reservation (AFET-W) model to simulate basin hydrology and create a “base condition” time series of stage and flow for locations throughout the Kissimmee Basin. AFET-W uses more current information (e.g., land use, existing legal uses) than the UKISS model, simulates a longer period of record (1965 to 2005), and has an expanded spatial domain that includes the LKB to the S-65E structure. An earlier version of the model (AFET) passed an external peer review that did not find any critical defects in the modeling tools (Loucks et al. 2008); AFET-W resulted from recalibration of AFET for a new set of reference evapotranspiration data. The AFET-W base condition includes all features of the completed KRRP (e.g., backfilling of C-38, removal of the S-65B and S-65C water control structures) using the 1996 HRS (alternative RS9D) for S-65 operations. Modeling results were presented in a previous draft technical document (SFWMD 2009). The analysis compared stage and flow duration curves for the base condition time series (representing water in the system) to a target time series representing the hydrologic needs of fish and wildlife. For this analysis, water was considered available for allocation if the duration curve for the base condition time series exceeded the curve for the target time series. Comparisons showed duration curves for the with-project base were below those for the upper threshold target time series for stage in the Headwaters Revitalization Lakes (SFWMD 2009, Figure 7-29 and Table 7-9), flows to the Kissimmee River at S-65 (SFWMD 2009, Figure 7-30), and stage in the Kissimmee River (SFWMD 2009, Figures 7-31 and 7-32). The results, therefore, indicate that all water not already allocated from the Kissimmee River and the Headwaters Revitalization Lakes reservation waterbodies (**Appendix A**, Figures A-8 and A-9) must be reserved. In other words, no additional water is available for allocation due to the overarching goals of restoration and protection of fish and wildlife in the public interest by the KRRP. The water is needed to ensure sufficient volume and timing of flow for Kissimmee River restoration. The peer-review panel, composed of five experts in the field, unanimously concluded that the approach was technically sound and the inferences and assumptions made regarding the linkages between hydrology and the protection of fish and wildlife were based on sound scientific information (Aday et al. 2009).

5.3 Establishment of Water Reservation Lines in the Upper Chain of Lakes

5.3.1 Approach

This section describes the development of hydrologic targets that protect fish and wildlife and their hydrologic requirements discussed in **Chapter 4**. Fish, amphibians, reptiles, birds, and mammals were considered during the development of the Water Reservations. The abundance of fish and wildlife is directly related to major wetland plant communities, which form the foundation and structure of fish and wildlife habitat associated with these waterbodies. The plant communities, in turn, depend on certain hydrologic requirements, which form the underpinnings of the hydrologic targets.

The UCOL reservation waterbodies are Lakes Hart-Mary Jane, Lakes Myrtle-Preston-Joel, the Alligator Chain of Lakes, Lake Gentry, East Lake Tohopekaliga, and Lake Tohopekaliga. An annual stage hydrograph was created for each of the six UCOL reservation waterbodies, which expresses the hydrologic requirements and annual water level pattern needed to protect existing fish and wildlife and their habitats in each waterbody (**Section 5.3.5**). Each hydrograph contains a water reservation line (WRL) that demarcates the boundary between water needed (at or below the line) and water not needed for the protection of fish and wildlife in the lake (above the line). The reservation hydrographs described here apply only to the UCOL, which are the lakes north of the Headwaters Revitalization Lakes. **Section 5.2** describes the approach used to determine the water needs of fish and wildlife in the Headwaters Revitalization Lakes and Kissimmee River reservation waterbodies.

Each reservation hydrograph was developed to capture the historical duration of inundation (hydroperiod), which is a critical factor in determining plant community composition (Hill et al. 1998, Keddy 2000, Keddy and Fraser 2000, Wilcox and Nichols 2008), habitat availability, and fish and wildlife assemblages (Williams et al. 1985, Johnson et al. 2007) between the highest and lowest water levels in a littoral zone. Capturing the hydroperiod patterns required for fish and wildlife in the reservation waterbodies was done by: 1) protecting representative seasonal water levels in each waterbody; 2) limiting the total volume available for withdrawal throughout the reservation waterbodies; and 3) limiting withdrawals based on downstream water levels in Lake Okeechobee. Together, these criteria directly protect some portion of annual hydroperiods and indirectly protect year-to-year variation due to downstream constraints (**Section 5.4**).

The approach used to establish the WRLs in the reservation hydrographs for the UCOL reservation waterbodies was based on several assumptions: 1) existing fish and wildlife habitats and resources in the reservation waterbodies reflect recent hydrology; 2) protecting historical seasonal highs, lows, and some portion of transitions between those events will protect current fish and wildlife resources; and 3) these protections are sufficiently captured in the reservation hydrograph, similar to a regulation schedule.

A water level regime can be characterized in many ways, including magnitude (e.g., high and low water levels), timing (seasonality), duration, frequency of flooding, and rate of change (recession and ascension rates). All these characteristics can be represented on an annual hydrograph, except for how they vary between years or over a multi-year period (interannual variation). Most of the fish and wildlife requirements identified for the UCOL reservation waterbodies are expressed in terms of stage, seasonality, duration, and recession/ascension rate that can be represented on an annual stage hydrograph. The long-term maintenance of habitat for fish and wildlife in the lakes also depends on annual variability based on rainfall patterns. The WRLs developed for the UCOL reservation waterbodies protect these requirements by defining an upper boundary that preserves much of the interannual variation in water levels in these lakes.

The total amount of wetland habitat available within a reservation waterbody is related to the water level regime. Lowering water levels can reduce the amount and change the type of wetland habitat available to fish and wildlife, in three primary ways: 1) decreasing the amount of inundated area available at a given time; 2) shortening the hydroperiod in shallow areas and increasing light penetration in deeper areas, both of which can alter plant communities; and 3) decreasing the accessibility of habitat to fish and wildlife by reducing the amount of time that water levels provide adequate depth.

The current stage regulation schedules constrain the maximum water level in the UCOL reservation waterbodies for the protection of public health and safety (i.e., flood protection). Water levels in the reservation waterbodies will rise to the regulation schedule when there is sufficient rainfall. These high-water events define the upper limit of wetland vegetation in the lakes and maximize the quantity and distribution of habitat available for use by fish and wildlife. Higher water levels occurred prior to regulation, which would have allowed wetland plant communities and their associated fish and wildlife to occupy higher elevations than they currently do (**Section 4.3.2**). The reservation hydrographs and WRLs capture the current maximum water level on November 1 for all lakes and capture varying extents of inundation throughout the year based on historical stage data in different waterbodies.

Almost 40 years have passed since completion of the water control structures in the UCOL and more than 30 years since the current regulation schedules were adopted and implemented by the USACE for the UCOL reservation waterbodies. The existing fish and wildlife resources and littoral habitats in these lakes reflect the varied, long-term hydrological patterns of the different reservation waterbodies. Therefore, developing

WRLs that account for the heterogeneity among systems also protects the flora and fauna adapted to those unique hydrological patterns. The process to develop the WRLs involved 1) specifying a seasonal high stage and duration; 2) specifying a seasonal low stage; 3) connecting the seasonal high stage to the seasonal low stage with a straight-line recession event; and 4) adjusting the resulting WRL to protect historical breeding season and wet season hydrological patterns (recession and ascension rates or breeding season water levels).

5.3.2 Seasonal High Stage

The WRL seasonal high stage defines an upper stage limit or threshold that preserves the maximum littoral extent in each waterbody, ensuring no reduction in wetland extent will occur below that elevation. For all UCOL reservation waterbodies, the seasonal high stage was specified as the high stage limit of the current stage regulation schedule and to occur beginning on the first day the schedule allows that stage to be reached (November 1). The region's rainy season generally ends in October, so the regulation schedules allow higher lake stages coincident with the onset of the dry season (reduced chance of flooding). Therefore, establishing the seasonal high stage early in the dry season preserves higher lake levels as close to the wet season as possible under the current regulation schedules. Establishing the WRL seasonal high stages at the same stage and timing as the authorized regulation schedule also captures the water levels required to maintain the current shoreward extent of littoral/wetland vegetation in these waterbodies.

The duration of time protected at the seasonal high stage for each reservation waterbody was determined by reviewing annual lake stages between November 1 and March 15 from 1971 to 2019. These months coincide with the maximum stages allowed under the current regulation schedules for most waterbodies. For each UCOL reservation waterbody, the average date when lake stages reached the maximum regulation schedule during this period was calculated, as was the proportion of time that stages met or exceeded the schedule during this period. In other words, the average date lake stages reached the maximum of the regulation schedule (if they did) and how many days lakes were at maximum stage on average were determined. These two periods were combined to determine the amount of protection for each waterbody at "high pool," or at the maximum stage allowed under the current regulation schedule. For example, if the average date a particular waterbody reached the maximum regulatory stage was December 8, and the average number of days spent at or above the regulatory schedule each year was 23 days, then the seasonal high stage of the WRL would extend from November 1 to December 31 (December 8 + 23 days = December 31). This method provides protection at current maximum stages for the average duration and timing of historical events for each waterbody, based on individual lake stages.

5.3.3 Seasonal Low Stage

Selection of the seasonal low stage established how much of the littoral zone can be dried out on an annual basis (i.e., it defines the boundary between truly aquatic vegetation and those that require regular drying events). Under the current regulation schedules, lake stages are managed to reach the same low stage on May 31 every year, providing storage capacity for flood control at the beginning of the wet season. In order to protect the extent of permanently flooded marshes, the WRL minimums were set as the minimum of the regulation schedules. This ensures that the extent of annual drying events would not be increased downslope from historical levels, which might lead to a reduction in overall open-water extent, or an expansion of the littoral zone lakeward (downslope).

5.3.4 Transition Between Seasonal High and Low Stages

After selecting seasonal high and low stages for the UCOL reservation waterbodies, recession rates were established based on a review of historical dry-season stage data for each waterbody. Most regulation schedules for these lakes allow up to maximum water levels until March 15 (except on Lakes

Myrtle-Preston-Joel, which begin receding after December 1), before declining to a seasonal low on May 31. However, actual historical stages between November 1 and March 15 vary substantially between waterbodies because of differences in lake operations, how the current regulation schedule was established, watershed size, and groundwater interactions, among other factors. For example, historical stages on March 15 typically are well below the maximum of the regulation schedule even without releases on some waterbodies (e.g., the Alligator Chain of Lakes), whereas others very often are near the maximum (e.g., Lake Gentry) (**Figure 4-5**). Therefore, historical dry-season and breeding-season hydrology varies between the waterbodies, especially relative to their respective regulation schedules. In order to protect these varying historical patterns, scientists selected the average daily stage on March 15 and drew recession lines between the seasonal high and seasonal low targets. The resulting WRLs have a two-stage recession for most waterbodies, with a shallower slope prior to March 15 and a steeper slope afterward, which mimics natural dry-season patterns driven by rainfall and evapotranspiration. However, due to historical stage variation between waterbodies, the WRLs differ relative to their regulation schedules and their shapes differ between waterbodies. Essentially, lakes with lower historical stages have lower WRLs relative to their regulation schedule (and vice versa), but the level of protection is similar throughout, based on individual historical stages.

The differences between WRLs among the reservation waterbodies represent historical inundation patterns and water management of each waterbody, and the protection of dry-season stages is similar regardless of how the WRL compares to its regulation schedule. In all cases, the maximum stages are protected at the regulatory schedule maximum, based on average durations of historical high-water events, and protection declines gradually throughout the breeding season to roughly the average daily stage by March 15. This varying protection provides a higher probability of achieving maximum lake stages in the beginning of the dry season, with gradually lower probabilities of high stages until mid-March, and tailors each WRL to the historical hydrology persistent in each system. Additionally, the difference in lake volume between the WRL and regulation schedules declines after March 15 because historical stages are closely driven by flood control releases during the recession phase of the regulation schedule.

Two waterbodies had an additional change to the WRL to accommodate breeding season recession rates of the endangered snail kite. Lake Tohopekaliga and East Lake Tohopekaliga support a large breeding population of snail kites from year to year, having supported up to 80% of statewide snail kite nesting activity in a given year (Cattau et al. 2008). Like many fish and wildlife species, snail kites are vulnerable to rapidly receding water levels during the breeding season (Fletcher et al. 2017). Unfortunately, that is how the flood control line in some of the regulation schedules is designed (e.g., a decline in stage of 1.2 ft per month from mid-March to June on Lake Tohopekaliga and East Lake Tohopekaliga). In order to accommodate slower water level recession rates but still provide as much inundated littoral habitat as possible for nesting, water managers typically release water from these lakes (if stages are high) between January and May, inducing a longer, slower reduction in lake stages than the flood control portion of the regulation schedule would require. Essentially, these operations more closely mimic naturally receding water levels through the dry season, rather than holding high lake stages into March and then rapidly releasing them to make room for flood control storage before June. However, because this is a relatively recent practice (approximately 10 years of operations), the average historical stage on March 15 in the 1972 to 2019 period of record is higher on Lake Tohopekaliga and East Lake Tohopekaliga than typically is experienced after implementation of managed recession rates. Therefore, the WRLs were adjusted to more closely match recession rates recently targeted by water managers and to protect breeding season habitat for endangered snail kites. The WRLs were adjusted to accommodate a straight-line recession from high to low pool beginning January 1. On East Lake Tohopekaliga, this reduced the WRL duration at the top of the regulation schedule by 1 day, and the WRL elevation on March 15 by 0.24 ft (7.3 cm) from what it would be using the same method as other lakes. On Lake Tohopekaliga, this reduced the WRL duration at the top of the regulation schedule by 21 days, and the WRL elevation on March 15 by 0.43 ft (13.1 cm). This change was not necessary for other UCOL reservation waterbodies due to lower average March 15 stages or to a lack of snail kite activity on those lakes.

Ascension rates from the seasonal low of the WRL were established in much the same fashion; the seasonal low stage was connected to the summer high stage with a straight line that would accommodate ascension rates of up to 1 ft (30.5 cm) per month. These ascension rates are slow enough that vegetation can keep up with rising water levels and reproduction requirements of fish and wildlife like apple snails and alligators are protected, but fast enough to capture early season rainfall and allow lake stages to recover from seasonal lows. The resulting WRLs protected the average daily lake stages or greater between June and August.

The largest difference between the WRLs and regulation schedules for most waterbodies occurs on June 1, which is when regulation schedules shift from prioritizing flood control to building water supply during the rainy season. This change in regulation schedule (from seasonal low to summer pool) varies from 0.5 ft on Lakes Hart-Mary Jane to 1.5 ft on Lake Gentry, East Lake Tohopekaliga, and Lake Tohopekaliga. While regulation schedules allow up to 1.5 ft higher stages on June 1 than on May 31, actual increases in water levels are a function of rainfall and watershed size and are reflected in the historical daily stage data. By reserving at least the average of daily stages from June to August, individual waterbodies' refill capacities are protected and reductions in wet season hydroperiod are limited to the 1- to 2-month period that the WRL is below the regulation schedule after June 1. In short, approximately the same percentile of historical stages is protected under the WRL on May 31 and June 1, but the difference between the WRL and regulation schedule on those days is substantial.

The approaches used to establish the WRLs described above do not represent a linear continuum of a certain percentile of historical stages between the seasonal high and seasonal low. The actual percentile values for each day of the WRL may fall between the 99th percentile (November 1 for the Alligator Chain of Lakes) and 22nd percentile (March 15 on Lake Tohopekaliga), depending on the waterbody and date. Furthermore, the actual future pattern of water level fluctuation in a reservation waterbody will depend on rainfall patterns, contributing surface water inflows, water management, and any permitted consumptive use. The threshold approach used to develop the reservation hydrographs does not explicitly address annual or interannual variation in water levels, but rather preserves the variability that occurs below the WRL). Combined with other rule constraints (**Section 5.4**), some portion of the interannual variability above the WRL is reserved as well, albeit at a less predictable rate than the portion under the WRL.

Changes in hydrologic conditions that may occur using the aforementioned approach to establish the WRL likely would manifest in the durations of inundation (hydroperiod) of the littoral marshes that lie between the seasonal high and low stages, and potentially the depth at which light penetration supports aquatic plant growth (especially submerged species at low elevations). These potential impacts were minimized by protecting at least the mean of daily stages through most of the dry season and by protecting the same highs and lows that are authorized under the current regulation schedules. Furthermore, by establishing the WRLs based on historical stages, the same general pattern of dry season recessions is preserved; long, slow, gradual recessions during historically drier systems (e.g., Alligator Chain of Lakes) and fast, managed recessions following high, stable stages in historically wetter systems (e.g., Lake Gentry).

5.3.5 Specific Water Reservation Lines for Lakes

Following the method described earlier, reservation hydrographs were developed for the six UCOL reservation waterbodies (**Figure 5-1**). For reference, the hydrographs also show the current stage regulation schedules that have been used for approximately the last 30 years as well as the interquartile range of average daily stages from May 1, 1971 to April 30, 2019 (Water Years 1972 to 2019) for each reservation waterbody.

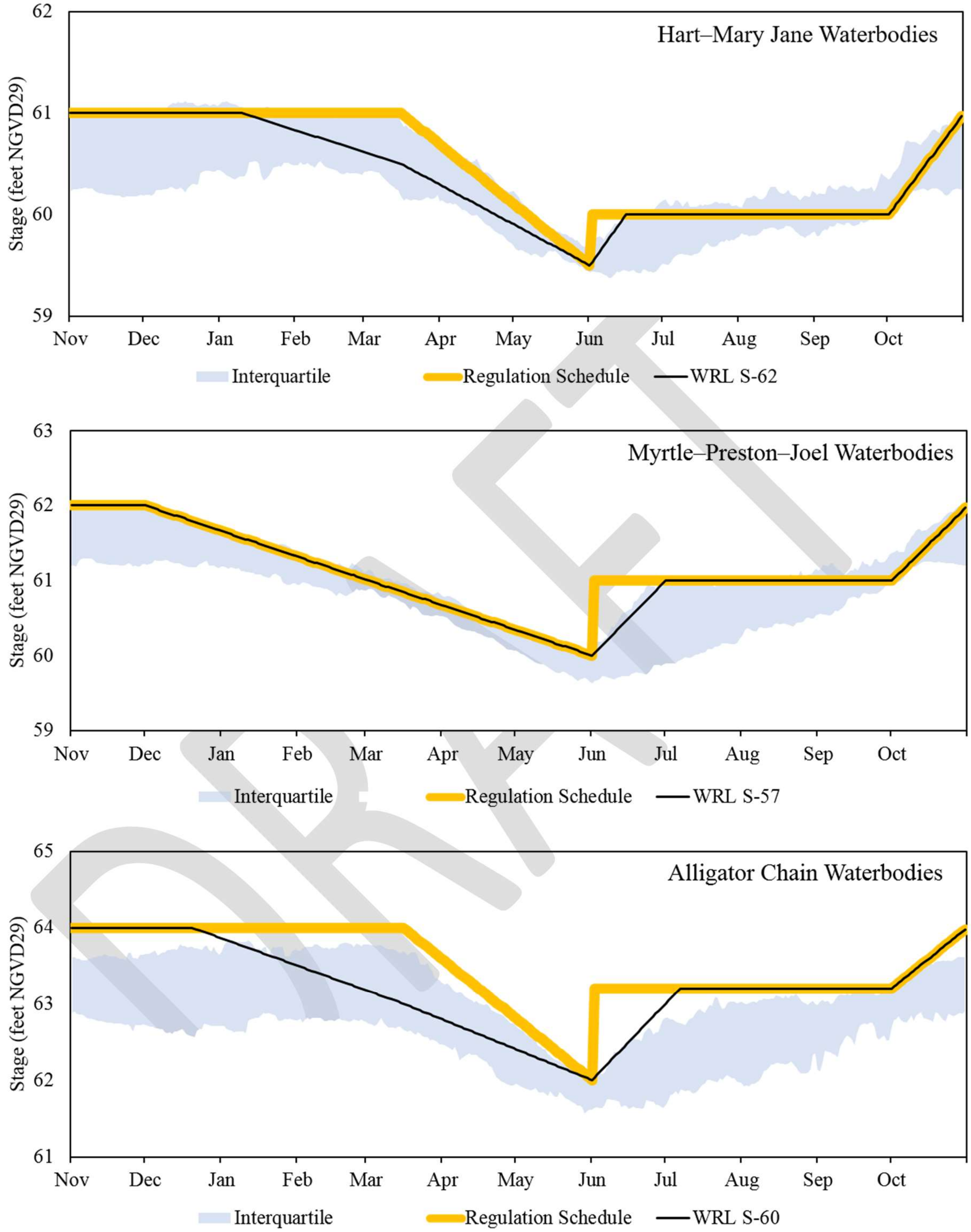


Figure 5-1. Water reservation hydrographs for the Lakes Hart-Mary Jane, Lakes Myrtle-Preston-Joel, and the Alligator Chain of Lakes reservation waterbodies. The water reservation line (WRL) is shown in black, and the federal regulation schedule is shown in yellow. The light blue shaded area represents the interquartile range (25th to 75th percentiles) of historical daily lake stages from May 1971 to April 2019.

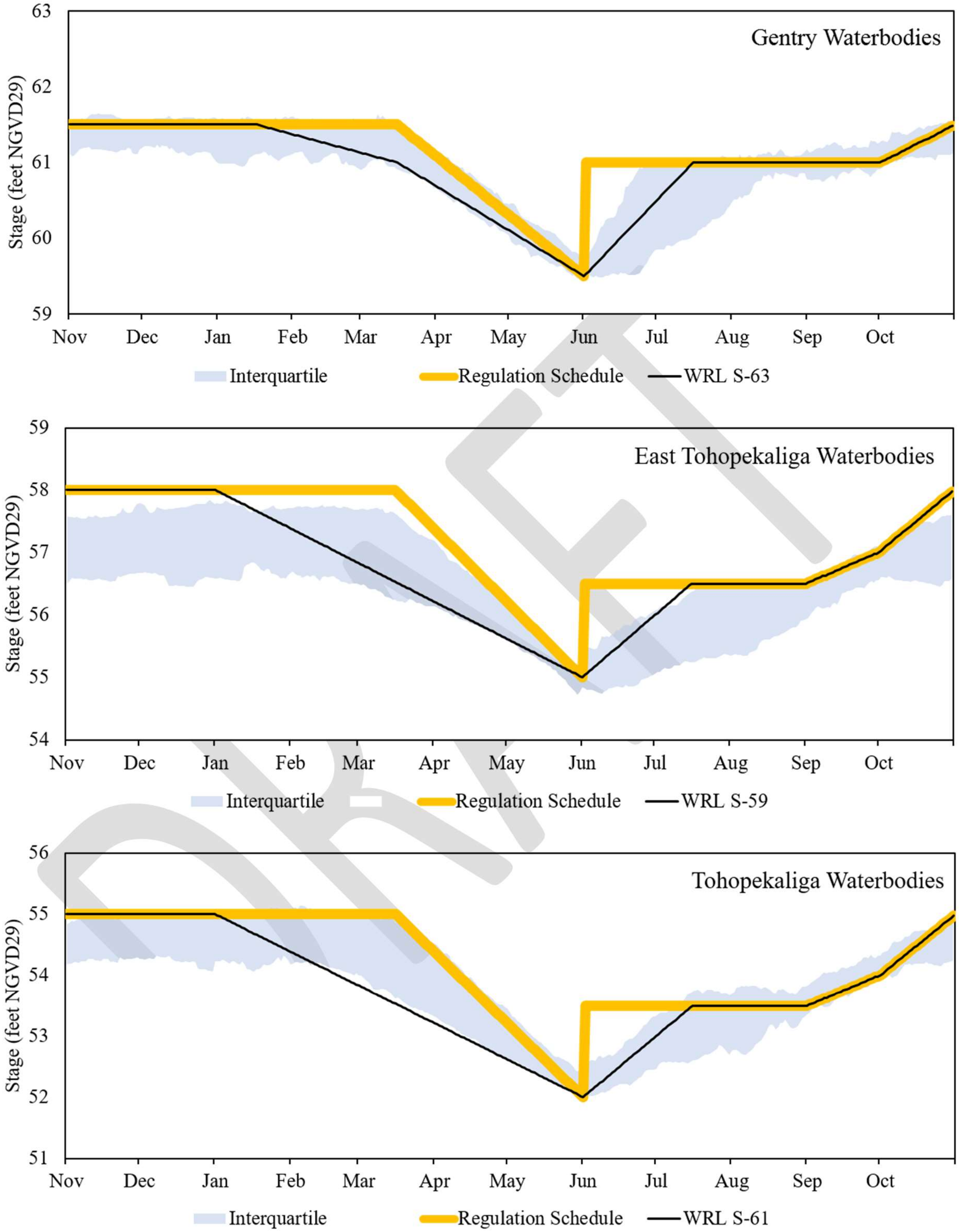


Figure 5-1 (cont.). Water reservation hydrographs for the Lake Gentry, East Lake Tohopekaliga, and Lake Tohopekaliga reservation waterbodies. The water reservation line (WRL) is shown in black, and the federal regulation schedule is shown in yellow. The light blue shaded area represents the interquartile range (25th to 75th percentiles) of historical daily lake stages from May 1971 to April 2019.

5.4 Impact Evaluation and Water to be Allocated

5.4.1 Existing Uses of Water from Proposed Reservation Waterbodies

Section 373.223(4), F.S., states that when establishing a Water Reservation, all presently existing legal uses of water shall be protected so long as such use is not contrary to the public interest. Existing water use permits were reviewed to determine the location and volumes under current allocations from the proposed reservation waterbodies. Historical uses also were identified. Permit selection included direct withdrawals of surface water from a reservation or contributing waterbody and withdrawals of groundwater from the SAS that could cause drawdown in a reservation waterbody. A search radius of 1 mile (1.6 km) around each proposed reservation waterbody was used to locate permitted groundwater withdrawals from the SAS.

Ninety-eight existing permits (**Table 5-1**) were identified that have at least one well completed in the SAS within 1 mile (1.6 km) of a reservation waterbody. In total, 5.7 million gallons per day (mgd) are allocated from the SAS within these 98 permits. Agricultural and livestock uses compose the majority of this volume. ~~Sixteen~~Thirteen existing permits (**Table 5-2**) were identified that withdraw surface water from reservation or contributing waterbodies, with a combined allocation of ~~70.7~~42.45 mgd. ~~Thirteen~~Ten of these permits are for agriculture. The largest allocation (~~22.8~~13.75 mgd) ~~belongs~~is attributed to ~~Wild Island Ranch~~Adams Ranch for withdrawals from ~~the~~ Lake ~~Istokpoga/Indian Prairie Canal System~~Marian. The Lake Toho Restoration/Alternative Water Supply Permit (49-02549-W) allows for diversion of water from East City Ditch and Mill Slough into an aboveground impoundment for the supplementation of Toho Water Authority's reclaimed water supply. Withdrawals for this permit are constrained by specific daily water levels in Lake Tohopekaliga, consistent with the 2017 draft Water Reservation rules that existed at the time of permit issuance.

As discussed in **Section 5.3**, fish and wildlife within the proposed reservation waterbodies have adapted to the existing hydrologic conditions and approved regulation schedules that have been in place since the 1980s. This includes the effects of documented and any potentially undocumented historical uses that have occurred. Existing legal users were granted water use allocations for withdrawal after all water use permitting criteria were met at the time of permit issuance or renewal. All historical uses are reflected in the observed stage and flow data that were part of the evaluation to determine the water to be reserved for protection of fish and wildlife in the Kissimmee River and KCOL. The data and modeling associated with this evaluation show that the water within the Kissimmee Basin system is driven primarily by climate (rainfall and evapotranspiration) and operations rather than historical uses. During wet years, floodplain inundation most likely will correspond with regulatory flood control releases from Lake Okeechobee to either the Caloosahatchee River or St. Lucie Estuary when there is less demand for water.

During the state and federal planning and feasibility studies process, it was determined that "there would not be a significant effect on Lake Okeechobee water supply with the restoration of the Kissimmee River" (USACE 1991). Resultant effects (reductions) also are not expected in Everglades National Park.

Table 5-1. Surficial aquifer system wells near the reservation waterbodies.

Permit Number	Project Name	Land Use	Average Daily Allocation (mgd)
28-00096-W	B and E Ranch and Grove	Livestock	0.0052
28-00016-W	Smith Okeechobee Farms	Agriculture	2.342
28-00290-W	Buckhorn Housing	Public Water Supply	0.0106
28-00379-W	Hidden Acres Estates	Public Water Supply	0.0192
28-00444-W	Trails End Fishing Resort	Public Water Supply	0.0103
28-00495-W	Butler Oaks Farm CNMP Implementation	Livestock	0.1945
28-00532-W	Depot Pasture Well	Livestock	0.0075
28-00538-W	B4 Inc., Dairy	Livestock	0.09
28-00551-W	Family Tree Lockett	Livestock	0.0027
28-00552-W	Ronald D Butler's Ranch	Livestock	0.0010
28-00646-W	Hickory Hammock – Equestrian Center	Livestock/Public Water Supply	0.0013
28-00650-W	Hickory Hammock – Istokpoga Boat Ramp	Public Water Supply	0.0012
28-00712-W	Pacos Ranch	Livestock	0.0026
28-00752-W	FRH Surficial Use	Livestock	0.0036
28-00769-W	Double Rock Ranch	Livestock	0.0445
47-00010-W	Lofton Ranch	Livestock	0.0006
47-00025-W	Clemons Okeechobee	Livestock	0.0171
47-00029-W	D Cross Ranch	Livestock	0.0072
47-00030-W	Bar Crescent S Ranch	Livestock	0.0262
47-00032-W	One Nine Cattle Company	Livestock	0.0084
47-00034-W	El Yolo 8	Agriculture	0.6302
47-00043-W	Eagle Island Farm	Agricultural	0.238
47-00381-W	Okeechobee Field Station	Landscape	0.0018
47-00498-W	Todd Clemons Grove	Agriculture	0.1897
47-00531-W	J A Tootle Property	Agricultural	0.0309
47-00706-W	Coquina Water Management (Office Well)	Public Water Supply	0.0005
47-00737-W	United States Army Corps of Engineering	Public Water Supply	0.0005
47-00880-W	Frances G Syfrett Ranch	Livestock	0.0062
47-00815-W	Raulerson and Sons Ranch	Agricultural/Livestock	0.8027
47-00836-W	Emory Walker Ranch	Livestock	0.0012
47-00837-W	Wallaces Brahmans	Agricultural/Livestock	0.0005
47-00856-W	Cabbage	Industrial	0.0068
47-00858-W	Lazy O Ranch	Livestock	0.0023
47-00880-W	Frances G. Syfrett Ranch	Livestock	0.0001
47-00894-W	Lamb Island and Dinner Island	Livestock	0.0035
47-00895-W	Dixie Pasture and KICCO Ranch	Livestock	0.0047
47-00908-W	Platts Bluff at Kennedy Farms	Livestock	0.0621
47-00913-W	Kissimmee Oaks	Livestock	0.0013
47-00923-W	Ruff Diamond	Livestock	0.0564
47-00925-W	Pete Beatty Ranch	Livestock	0.042
47-00928-W	MICCO (Bassinger)	Livestock	0.0063
47-00931-W	Horse Farm (68)	Livestock	0.0107
47-00932-W	Cracker Trail Country Store	Public Water Supply	0.0016
47-00934-W	C Hooker Farm	Livestock	0.0019
47-00940-W	Watford Cattle Company	Livestock	0.0041
47-00943-W	Thoroughbred Estates	Landscape	0.0158
47-00959-W	Alton Chandler Civic Center	Public Water Supply	0.0001
47-00979-W	Bassinger Shop Calves	Livestock	0.003
47-00988-W	101 Ranch Hwy 98	Livestock	0.0024
47-01025-W	Rocking J E Ranch (Cattle)	Livestock	0.0220
47-0126-W	CNC Ranch	Livestock	0.0102
47-01135-W	Corona Cattle Company	Livestock	0.0190
47-01149-W	Rocking E Ranch	Agriculture	0.1019

Permit Number	Project Name	Land Use	Average Daily Allocation (mgd)
47-01157-W	Robert Monroe Arnold	Livestock	0.0066
47-01192-W	Yates Marsh Lease/Kenedy Farms, Inc.	Livestock	0.0007
47-01193-W	Doug Marshall	Livestock	0.007
47-01241-W	Four K Ranch Lippencott	Livestock	0.0003
47-01270-W	Phitsini Elenburger	Agriculture	0.0242
47-01280-W	RMSCO Ranch	Agriculture	.0055
47-01298-W	Kennedy Farms, Inc. River Parcel	Livestock	0.0018
47-01373-W	Harmony Ranch	Nursery	.0121
47-01375-W	Camp Grace	Public Water Supply	0.0074
47-01380-W	C&R Groves	Agriculture	0.083
47-01394-W	Kissimmee Oaks Cattle	Livestock	0.0002
47-01401-W	Matt Johnson	Landscape	0.0033
47-01407-W	Robert Stark	Landscape	0.0065
47-01415-W	Chicken Coop	Agricultural	0.0008
48-02079-W	Southpark Circle Irrigation	Landscape	0.0106
48-02646-W	FedEx Ground	Landscape	0.0031
48-02663-W	Pedro Ordehi	Agricultural	0.0069
49-00450-W	Wild Florida	Public Water Supply	0.0155
49-00930-W	Marsh Landing	Landscape/Public Water Supply	0.003
49-00937-W	OGRVP, LLC	Public Water Supply	0.0133
49-02599-W	Lake Marian Restaurant	Public Water Supply	0.0001
49-01023-W	Joh-Vannah Nursery Inc	Nursery	0.0148
49-01041-W	Iglesia Bautista Central	Public Water Supply	0.0010
49-01135-W	Kissimmee Field Station	Public Water Supply	0.0041
49-01192-W	Flora Express Inc	Nursery	0.1397
49-01253-W	Les Murdock	Livestock	0.0001
49-01479-W	Adams Ranch	Livestock	0.0420
49-01674-W	Silver Spurs Club	Landscape/Public Water Supply/Livestock	0.0041
49-01678-W	Griffis Estates	Livestock	0.0003
49-01737-W	C E Outdoor Services Nursery	Nursery	0.0558
49-01827-W	Neptune Road Widening	Landscape	0.0092
49-01882-W	4433 O B T-Repair Shop	Public Water Supply	0.0002
49-01949-W	Sunshine Greenery Nursery	Nursery	0.0077
49-01985-W	Twin Lakes	Agricultural	0.17
49-02256-W	Fells Cove	Landscape	0.0058
49-02281-W	Premium Peach LLC	Agricultural	0.0044
49-02331-W	Home Rehab Source-Zuni Road	Landscape	0.0171
49-02348-W	Bexley Ranch/Lake Marian	Livestock	0.0172
49-02516-W	Poinciana Personal Storage	Landscape	0.0031
49-02703-W	El Maximo Livestock	Livestock	0.0241
53-00263-W	Lake Loft Well	Landscape	0.0184
53-00265-W	Highway 60 Plant Nursery	Nursery	0.0300
53-00271-W	Shady Oaks Limited Use WTF	Public Water Supply	0.0003
53-00297-W	Lake Hatchineha Ranch LLC	Public Water Supply/Livestock	0.0054
53-00327-W	ORFIBLU	Agricultural	0.0132
		Total	**5.705**

mgd = million gallons per day.

Table 5-2. Surface water pumps near the reservation waterbodies.

Permit Number	Project Name	Land Use	Source	Average Daily Allocation (mgd)
~~28-00130-W~~	~~Wild Island Ranch~~	~~Agriculture~~	~~Lake Istokpoga/Indian Prairie Canal System~~	~~22.84~~
~~28-00146-W~~	~~Fort Basinger Grove~~	~~Agriculture~~	~~Istokpoga Canal and C-41A Canal~~	~~0.29~~
~~28-00116-W~~	~~Smith Okeechobee Farms~~	~~Agriculture~~	~~SFWMD C-41A Canal~~	~~5.123~~
28-00357-W	River Grove	Agriculture	C-38 Canal	5.71
49-00051-W	Lakeside Groves, Inc.	Agriculture	Live Oak Lake	0.23
49-00077-W	Number 4 Grove	Agriculture	Pearl Lake	0.50
49-00097-W	Turkey Hammock	Agriculture	Lake Kissimmee	3.23
49-00150-W	Macy Island Citrus	Agriculture	Lake Tohopekaliga	0.15
49-00776-W	Adams Ranch	Agriculture	Lake Marian	13.75
49-00938-W	Heart Bar Ranch Seed and Sod	Agriculture	On-site canal (drains to the C-34 Canal)	0.78
49-01409-W	Shingle Creek Stormwater Reuse	Public Water Supply	Shingle Creek	6.00
49-01960-W	Lakeshore Stormwater Augmentation	Public Water Supply	Lake Tohopekaliga	2.00
49-02330-W	Bexley Ranch/Lake Marian	Agriculture	Lake Marian	1.28
53-00031-W	Grove Number 91	Agriculture	Lake Pierce	0.42
53-00032-W	Chastain Block	Agriculture	Lake Pierce	0.18
49-02549-W	Lake Toho Restoration/AWS	Public Water Supply	East City Ditch/Mill Slough	8.22
			Total	~~70.703~~42.45

mgd = million gallons per day.

5.4.2 Downstream Threshold at S-65 for the Kissimmee River Restoration Project

An evaluation was performed to ensure future water withdrawals from the reservation waterbodies will not exceed a threshold that negatively affects downstream restored systems (i.e., KRRP) due to insufficient flows. The determination of an acceptable level of change in flows at the S-65 structure was based on the range of acceptability concept developed during earlier technical work for the Water Reservations that was peer reviewed in 2009. In the earlier technical work, the range of acceptability was applied to the river performance by selecting targets for the performance measures that represented an upper and lower range of hydrologic conditions that should be equally protective of fish and wildlife. The use of the upper and lower performance measure targets to create an upper and lower threshold target time series of discharge is described in more detail in Section 7 of SFWMD (2009).

Average discharge at the S-65 structure was 976 cfs for the lower threshold target time series and 1,077 cfs for the upper threshold time series. An acceptable level of change in discharge should be less than the difference between the average discharges of the upper and lower threshold target time series. Using the reduction from the upper threshold to the midpoint between the upper and lower threshold averages should provide a margin of safety. The midpoint between the average S-65 discharge for the upper and lower thresholds is 1,026.5 cfs. The difference between the average discharge for the upper threshold and the midpoint between the upper and lower threshold is 50.5 cfs. A reduction from the upper threshold to the midpoint is $(1{,}077 - 1{,}026.5)/1{,}026.5 \times 100\% = 5\%$. This suggests that a reduction of less than 5% should be acceptable to protect the water needed for fish and wildlife.

A conservative analysis was performed to look at a hypothetical reduction in flows at the S-65 structure from future withdrawals to determine what effect this would have on the KRRP performance measures. For this analysis, mean daily discharge was reduced 5% every day for a 41-year period (1965 to 2005). The effect of this hypothetical reduction in flows was evaluated by changes in the number of days (duration) of floodplain inundation and the duration of low flows.

The draft Water Reservation rules limit withdrawals within each UCOL reservation waterbody based on the WRL, while restricting all surface water withdrawals from the Headwaters Revitalization Lakes and the Kissimmee River and floodplain. An added level of protection was incorporated into the draft Water Reservation rules, requiring an applicant demonstrate that its proposed withdrawal, individually and cumulatively with all withdrawal allocations permitted since 2005, do not reduce average discharges at the S-65 structure by more than 5% compared to the no-withdrawal scenario over a range of climatic variability between 1965 and 2005. In 2009, it was determined that a less than 5% reduction in average flows to the Kissimmee River would not result in impacts to the river. A water use permit was issued to Toho Water Authority in 2017 (Water Use Permit 49-02549-W; **Table 5-2**) that reduced the average cumulative discharges at S-65 by 0.82%. As a result, the reduction of future cumulative discharges at S-65 has been reduced to 4.18% (5% – 0.82% = 4.18%), which is reflected in the draft Water Reservation rules. This individual and cumulative downstream check at the S-65 structure provides an extra level of assurance that future water uses will not adversely affect the water needed for the protection of fish and wildlife in the Kissimmee River and Chain of Lakes or the ecological integrity goal of the KRRP.

5.4.3 Lake Okeechobee Constraint for the Lake Okeechobee Service Area

Restricted Allocation Area (RAA) criteria are established by rule for specific sources where there is insufficient water to meet projected needs. In October 2008, the SFWMD Governing Board adopted RAA criteria for the Lake Okeechobee Service Area (LOSA) (Subsection 3.2.1.F of the Applicant's Handbook (SFWMD 2015b)). The LOSA RAA criteria were established to address lower lake management levels and storage under the USACE's interim Lake Okeechobee Regulation Schedule (2008 LORS). The RAA criteria were incorporated into the Minimum Flow and Minimum Water Level (MFL) recovery strategy for Lake Okeechobee when the MFL strategy changed from prevention to recovery. **Figure 5-2** shows the spatial extent of the LOSA RAA. The 2008 amendment (SFWMD 2008) to Appendix H of the *2000 Lower East Coast Water Supply Plan* contains background information on the regulatory context for Lake Okeechobee's change to an MFL recovery strategy, the LOSA RAA, and future expectations for the lake's MFL status.

The LOSA RAA criteria generally limit surface water withdrawals from Lake Okeechobee and all surface waters hydraulically connected to the lake to base condition water uses occurring from April 1, 2001 to January 1, 2008. For surface water users in LOSA, studies and analyses supporting the 2008 LORS projected a decline in the physical level of certainty of agricultural uses reliant on lake water supplies, from a 1-in-10 year to a 1-in-6 year drought return frequency (SFWMD 2018).

Public comment received in 2015 from LOSA agricultural users expressed concerns that future withdrawals in the UKB would reduce their level of certainty below the 1-in-6 drought frequency currently predicted under 2008 LORS. To prevent this from occurring and to protect existing legal users within LOSA, a downstream Lake Okeechobee constraint has been incorporated into the draft Water Reservation rules.

The Applicant's Handbook (SFWMD 2015b) will be revised simultaneously with adoption of the draft Water Reservation rules [Chapter 40E-10, Florida Administrative Code] to include new criteria pertinent to water withdrawals from reservation and contributing waterbodies, including a requirement and criteria for water use permit applicants to demonstrate the proposed use will not impact existing legal users in LOSA. To provide such assurance, a permittee will be required to perform a daily downstream check of Lake Okeechobee stage prior to withdrawing surface water or groundwater from a reservation or contributing waterbody. Withdrawals can only occur when regulatory releases from Lake Okeechobee are being made to either the Caloosahatchee River or St. Lucie Estuary and other regulatory constraints are met.

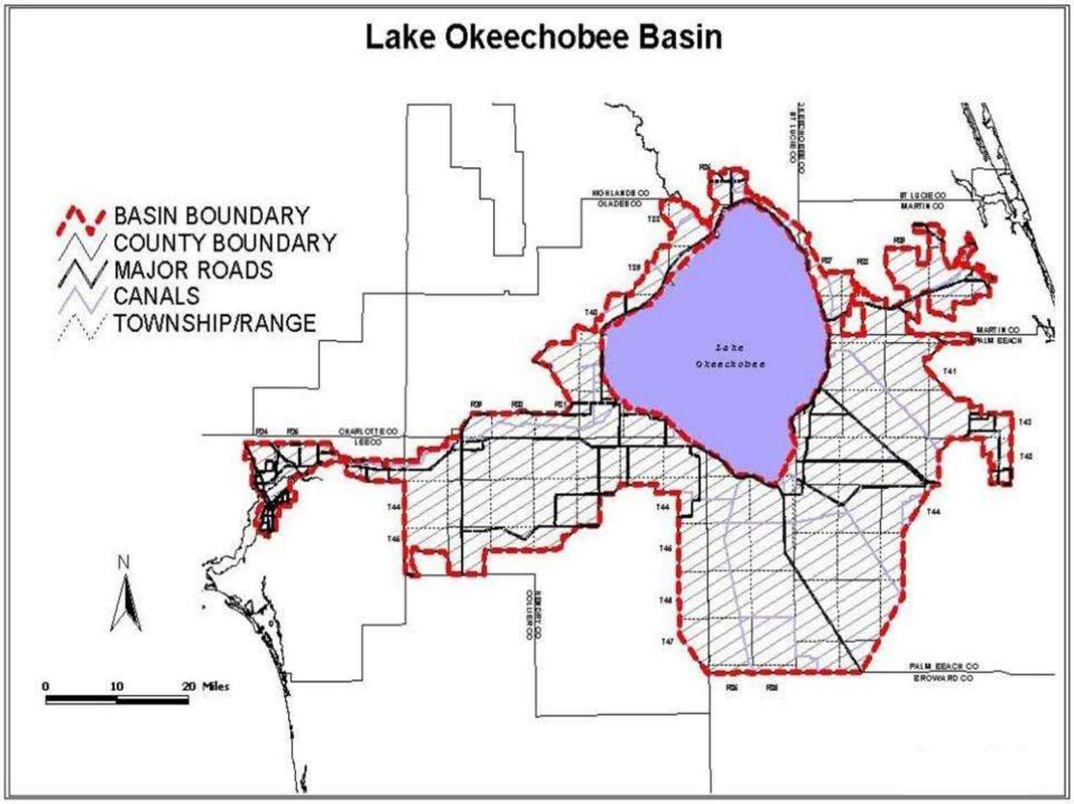


Figure 5-2. The Restricted Allocation Area rule boundary for the Lake Okeechobee Service Area.

5.5 Modeling Tool for Evaluating Future Water Use Withdrawals

To assist with the evaluation and permitting of future water use withdrawals, the Upper Kissimmee Operations Simulation (UK-OPS) Model was developed. The UK-OPS Model directly computes the allowable timing of proposed withdrawals consistent with the constraints and criteria in the draft Water Reservation rules. This section provides an overview of the UK-OPS Model and a hypothetical example withdrawal scenario to demonstrate the model capabilities and outputs. More detailed information regarding the UK-OPS Model is provided in **Appendix C**.

5.5.1 Overview of the Upper Kissimmee – Operations Simulation Model

The UK-OPS Model is a coarse-scale water management hydrologic simulation model developed to quickly test alternative water operation strategies. Additional model features were created to evaluate the effects of surface water withdrawals based on the draft Water Reservation rules.

The increasing utility and computational power of Microsoft Excel® made the spreadsheet software program a logical platform to build the UK-OPS Model. The model is a simple, daily time-step, continuous simulation model of the hydrology and operations in the primary UKB lakes. Analysts can use the UK-OPS Model to easily test a variety of operating strategies and quickly receive feedback of the performance for the primary lake management objectives.

The UK-OPS Model and documentation report were peer reviewed in November 2019. The model was deemed technically sound, appropriately developed, and usable for the intended applications. Technical details of the UK-OPS Model are provided in **Appendix C**. **Appendix D** contains the peer-review reports.

5.5.2 Sensitivity Analysis of Hypothetical Water Supply Withdrawals with Kissimmee Water Reservation Criteria

The UK-OPS Model investigated effects of hypothetical water supply withdrawals from UCOL waterbodies with the constraints and criteria in the draft Water Reservation rules. Water supply withdrawal reliability was assessed with and without the proposed Lake Okeechobee constraint discussed in **Section 5.4.3**. A sensitivity analysis was conducted to evaluate the effects of hypothetical water supply withdrawals from one UCOL reservation waterbody, Lake Tohopekaliga. Results of the sensitivity analysis are presented in the following sections. **Figures 5-3** and **5-4** illustrate example WRLs for East Lake Tohopekaliga and Lake Tohopekaliga, respectively. The red dashed line is a draft of the WRL (since modified as shown in **Section 5.3.5** and **Appendix B** as black lines), which was designed to protect the water needed for protection of fish and wildlife in the lake system. The general concept is that water withdrawals can occur if the lake stage is above the WRL. For example, if water withdrawals are contemplated from the Lakes Hart-Mary Jane reservation waterbody, then the daily stage must exceed the WRL for that day before a withdrawal can occur. A Lake Okeechobee constraint was added to the draft Water Reservations rules to prevent impacts to downstream users within LOSA. If the rule constraints are met, then withdrawals can occur on that day. The process to check these rule constraints repeats each day of the simulation.

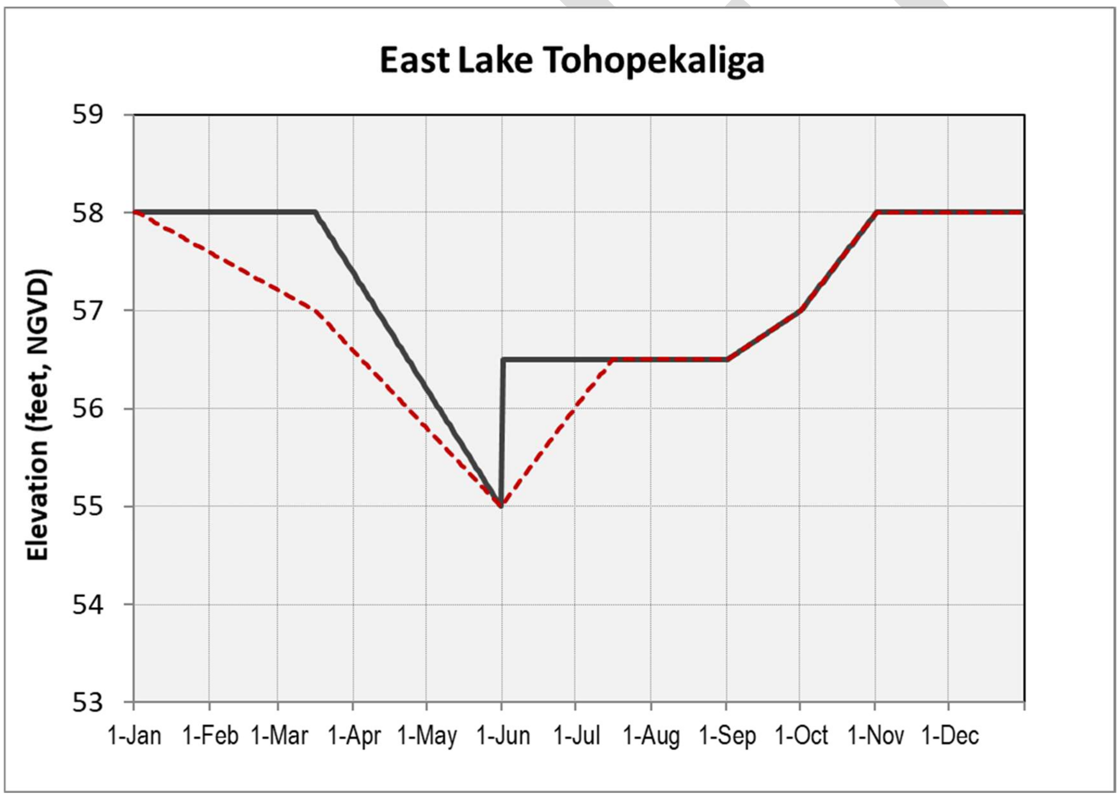


Figure 5-3. East Lake Tohopekaliga regulation schedule (black line) and a draft water reservation line (red dashed line).

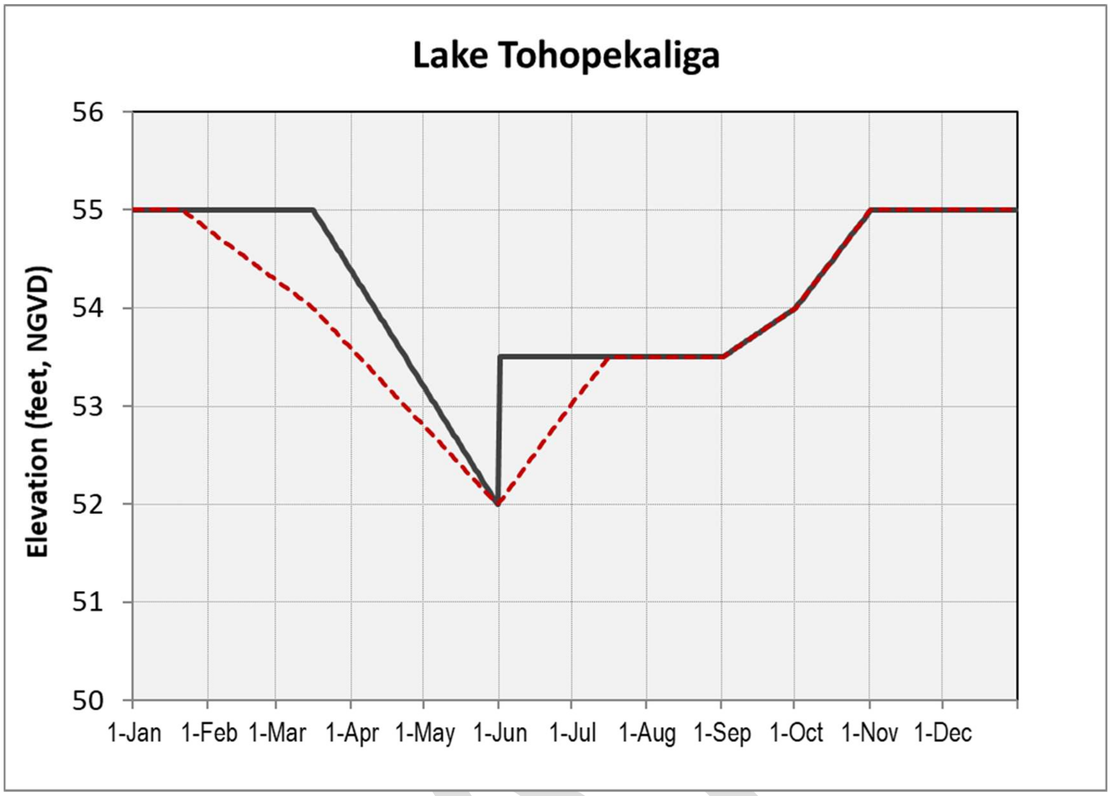


Figure 5-4. Lake Tohopekaliga regulation schedule (black line) and a draft water reservation line (red dashed line).

5.5.2.1 Baseline Scenario

The first scenario simulation (hereafter referred to as Base) was a baseline that used the authorized HRS and the standard regulation schedules for East Lake Tohopekaliga and Lake Tohopekaliga (**Figures 5-3** and **5-4**, respectively). No water supply withdrawals were assumed.

5.5.2.2 Water Supply Withdrawal Scenario 1

Scenario 1, hereafter WSmax, used the same assumptions as the Base but included water supply withdrawals from Lake Tohopekaliga. The capacity of the infrastructure needed to make the withdrawal was fixed at 64 mgd (99 cfs), but the daily withdrawal rate was subject to the constraints and criteria in the draft Water Reservation rules. No other water supply withdrawals from other lake systems were assumed in this hypothetical scenario.

5.5.2.3 Water Supply Withdrawal Scenario 2

Scenario 2, hereafter WSmaxL, was identical to Scenario 1 except for the addition of the Lake Okeechobee constraint. The Base simulation was used for the relative comparison. Comparison with WSmax also was informative. The Lake Okeechobee constraint was designed to limit adverse impacts to existing legal users in LOSA. Withdrawals from UCOL reservation waterbodies could reduce water availability downstream. The Lake Okeechobee constraint limits withdrawals from UCOL reservation waterbodies to occur only when regulatory releases from Lake Okeechobee are occurring to either the Caloosahatchee River or St. Lucie Estuary.

The approximation of the Lake Okeechobee constraint is depicted in **Figure 5-5**. When the stage is above the Low Sub-band of the 2008 LORS, indicating regulatory releases are being discharged to tide, the hydrograph is green. The hydrograph is red when the stage is below the Low Sub-band of the 2008 LORS, indicating relatively low water conditions with no regulatory discharge to tide. When the lake stage is red, the Lake Okeechobee constraint is not met and no water supply withdrawals can be made from reservation or contributing waterbodies. When the lake stage is green, indicating regulatory releases are occurring from Lake Okeechobee to either the Caloosahatchee River or St. Lucie Estuary, then the Lake Okeechobee constraint is met and withdrawals are allowed from reservation or contributing waterbodies, provided all other regulatory constraints (criteria) are met. This approximation of the Lake Okeechobee constraint is tied to the 2008 LORS when regulatory releases occur, but it can be modified as needed when a revised regulation schedule is implemented for Lake Okeechobee. The objective is to capture the timing of when regulatory releases are discharged to tide.

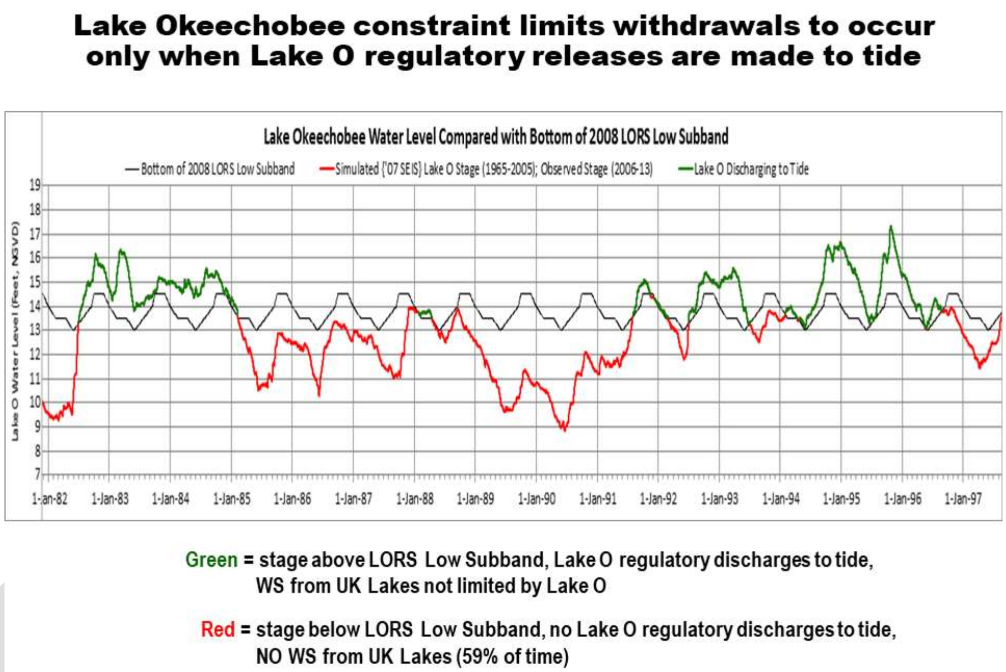


Figure 5-5. Lake Okeechobee constraint used by the UK-OPS Model.

5.5.2.4 Simulation Results

The UK-OPS Model simulations of the Base, WSmax, and WSmaxL scenarios revealed the effects of one possible withdrawal scenario on the constraints and criteria of the draft Water Reservation rules. The outputs examined and presented here are limited to comparisons of Lake Tohopekaliga water budgets and stage percentiles, S-65 annual flow, and water supply reliability.

Lake Tohopekaliga Water Budget

Figure 5-6 shows the Lake Tohopekaliga annual water budget for the WSmax and WSmaxL simulations. The water supply withdrawal component is shown for each simulation year and is small relative to the other water budget components. The WSmaxL scenario has less volume of withdrawal. Annual average withdrawal reduces from 39,000 acre-feet per year for WSmax to 19,000 acre-feet per year for WSMaxL, a 51% reduction. The reduction is due to the Lake Okeechobee constraint, which reduces the number of days surface water or groundwater withdrawals can be made.

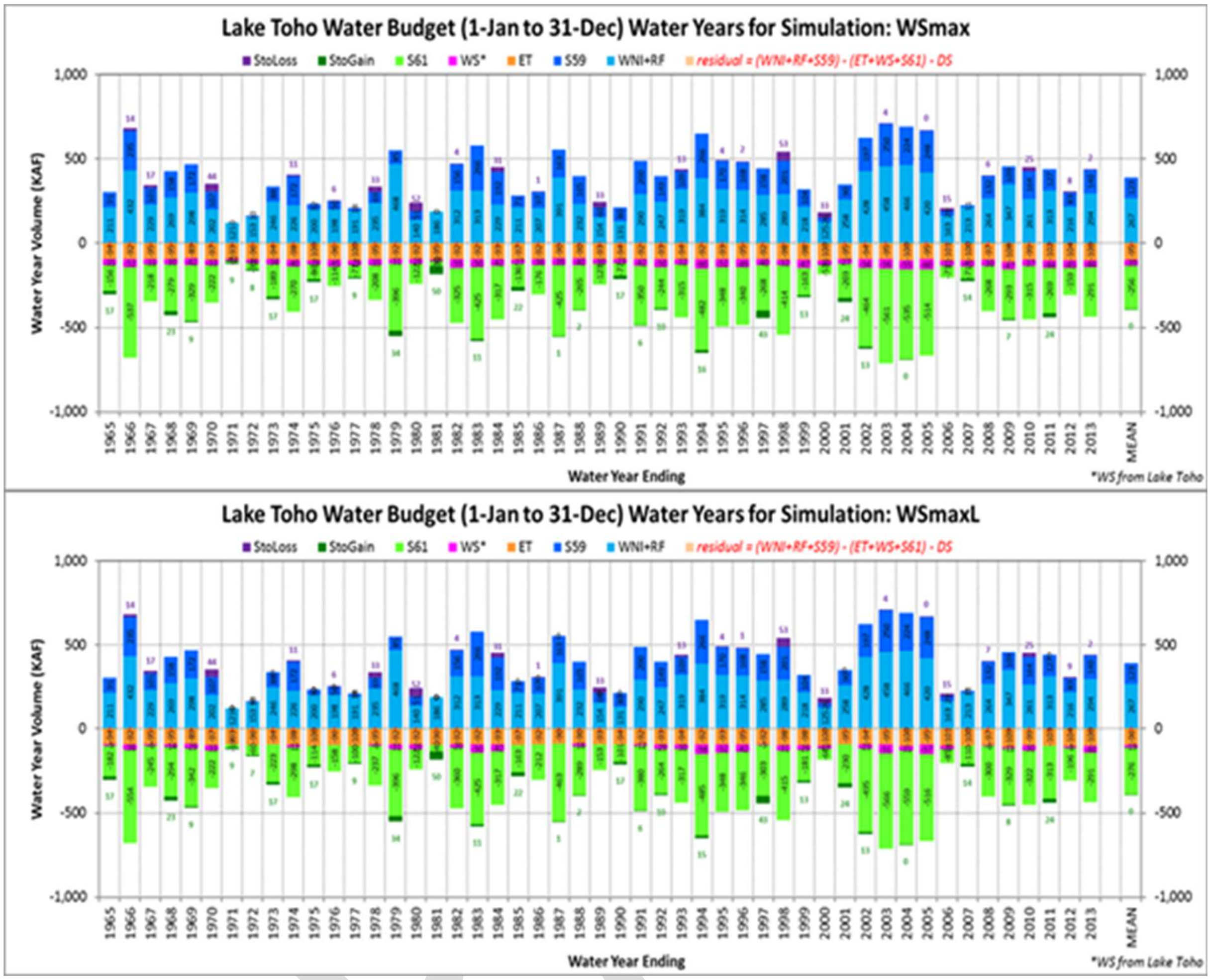


Figure 5-6. Water budget comparison of WSmax and WSmaxL for Lake Tohopekaliga.

Lake Tohopekaliga Stage Percentiles

Figure 5-7 compares the lake stage percentiles for the three simulations. Results demonstrated a downward shift in the percentiles of the WSmax scenario (red) relative to the Base (black). The WSmaxL scenario (green) falls between the other simulations because the withdrawals are less than those of the WSmax simulation.

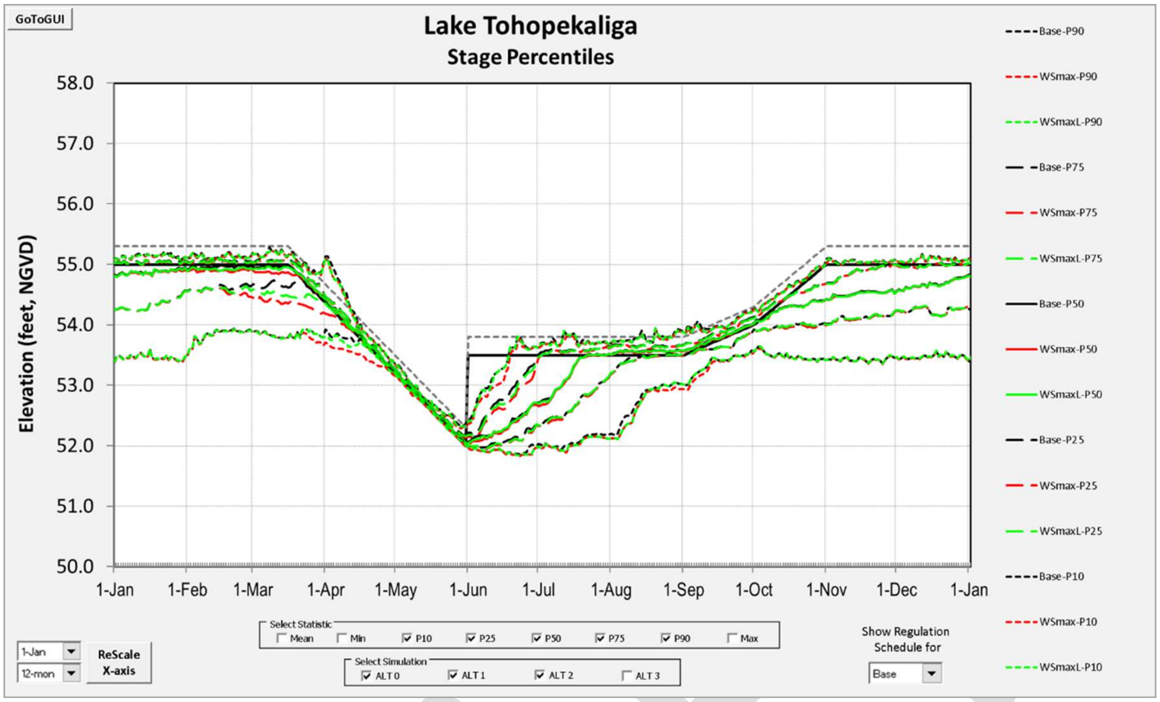


Figure 5-7. Lake Tohopekaliga stage percentiles.

S-65 Annual Flow

A key threshold for the draft Water Reservation rule criteria is that the reduction in mean annual flow for the 41-year simulation period cannot exceed 5%. This permitting criterion will be used for evaluating future withdrawals. This criterion is not, nor can it be, a criterion for real-time operations to determine if withdrawals can occur. This permitting criterion is evaluated at the time an applicant submits a water use permit application to ensure the proposed withdrawal does not impact restoration efforts associated with the KRRP or the water needed for protection of fish and wildlife.

Figure 5-8 shows the mean annual flow for the WSmax scenario is exactly -5.0%. The maximum withdrawal capacity of 64 mgd was determined by iteratively running the model until this limit was reached. Thus, if all future water supply withdrawals were to come from Lake Tohopekaliga, they could not exceed a total of 64 mgd. Withdrawals permitted in the future likely will be in various amounts and from any of the six lake systems that allow withdrawals, subject to the WRLs and downstream constraints. This is one reason why the UK-OPS Model is needed: to evaluate each proposed withdrawal in the context of the accumulated withdrawals that have already been permitted. As discussed previously, one water use permit recently was authorized, leaving only 4.18% of future reductions in the mean annual flow at the S-65 structure. Once the 5% threshold is reached, no further withdrawals will be permitted.

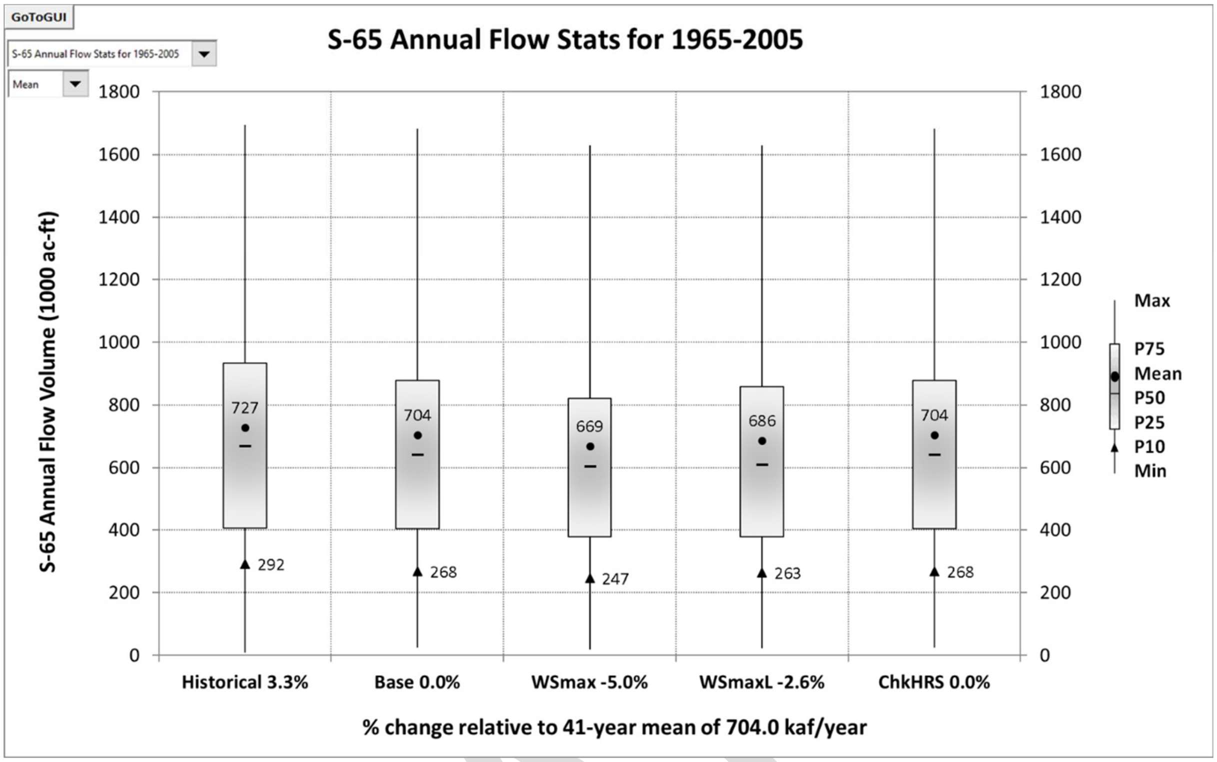


Figure 5-8. Annual flow at the S-65 structure.

Water Supply Reliability

The simulated water supply reliability information for the WSmax and WSmaxL scenarios are shown in **Tables 5-3** and **5-4**, respectively. The target reliability (percent of time water supply withdrawals occur) was set at 70%. Users can change this target to match the level of performance desired for their particular project. The table summaries show the reliability with the WSmax scenario is 8 calendar years out of the 49 years simulated. The WSmaxL scenario has only 4 years out of 49 years simulated that meet or exceed the 70% reliability target. This result illustrates the impact of the Lake Okeechobee constraint. A larger pump size can be tested to determine if supply targets can be better met. The reliability measures reflect the timing of withdrawals, but larger withdrawals could occur within the allowable days if they do not exceed the 5% limit described previously. These scenarios can be tested using the UK-OPS Model.

Table 5-3. Lake Tohopekaliga water supply reliability for the WSmax scenario.

	Lake TOH Water Supply Reliability Table for WSmax															Percent of Time WS Withdrawal			
	No. of Days per Month with Lake Toho WS Withdrawals at 99.0 cfs (64.0 MGD)												Days	Vol(kaf)	AvgMGD	CalYear	WetSeas	DrySeas	WatYear
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	May-Oct	Nov-Apr	May-Apr
1965	0	16	31	30	31	1	9	31	8	7	0	14	178	34.96	31.21	48.8%	47.3%		
1966	23	28	31	30	31	14	31	31	30	15	0	0	264	51.85	46.29	72.3%	82.6%	74.1%	58.4%
1967	0	16	31	30	31	0	8	31	20	1	0	0	168	33.00	29.46	46.0%	49.5%	50.9%	62.7%
1968	0	0	0	25	31	26	30	31	10	0	0	0	153	30.05	26.75	41.8%	69.6%	26.3%	31.7%
1969	19	28	31	30	31	0	0	0	6	27	21	22	215	42.23	37.70	58.9%	34.8%	65.6%	64.7%
1970	31	28	31	30	31	9	0	10	0	0	0	0	170	33.39	29.81	46.6%	27.2%	91.5%	62.2%
1971	0	0	3	28	31	0	0	0	0	0	0	0	62	12.18	10.87	17.0%	16.8%	29.2%	22.2%
1972	0	0	13	30	31	0	6	23	6	0	0	0	109	21.41	19.06	29.8%	35.9%	34.7%	20.2%
1973	0	26	31	30	31	3	0	13	29	11	0	0	174	34.18	30.51	47.7%	47.3%	55.7%	41.9%
1974	0	14	31	30	31	2	30	31	30	4	0	0	203	39.87	35.59	55.6%	69.6%	50.0%	44.4%
1975	0	0	21	30	31	0	0	27	19	11	2	0	141	27.70	24.72	38.6%	47.8%	38.7%	49.0%
1976	4	29	31	30	31	19	28	29	26	2	0	0	229	44.98	40.04	62.6%	73.4%	59.6%	50.3%
1977	5	28	31	30	31	1	0	5	13	2	0	3	149	29.27	26.13	40.8%	28.3%	59.0%	62.7%
1978	19	28	31	30	31	0	6	29	3	0	0	0	177	34.77	31.04	48.5%	37.5%	67.0%	44.7%
1979	4	28	31	30	31	1	0	0	27	7	0	0	159	31.23	27.88	43.6%	35.9%	58.5%	44.4%
1980	20	29	31	30	31	3	0	0	0	0	0	0	144	28.28	25.18	39.3%	18.5%	66.2%	48.1%
1981	0	0	0	0	11	4	0	3	21	0	0	13	52	10.21	9.12	14.2%	21.2%	5.2%	9.3%
1982	25	28	31	30	31	30	31	31	28	13	0	0	278	54.60	48.74	76.2%	89.1%	74.5%	45.5%
1983	7	28	31	30	31	13	20	31	28	13	7	15	254	49.89	44.54	69.6%	73.9%	59.9%	71.2%
1984	31	29	31	30	31	3	27	30	4	0	0	0	216	42.43	37.77	59.0%	51.6%	81.7%	76.2%
1985	0	0	9	30	31	0	0	30	27	10	0	0	137	26.91	24.02	37.5%	53.3%	33.0%	36.7%
1986	30	28	31	30	31	0	0	23	12	0	0	0	185	36.34	32.44	50.7%	35.9%	70.8%	59.5%
1987	29	28	31	30	31	2	0	0	0	0	19	29	199	39.09	34.89	54.5%	17.9%	70.3%	50.4%
1988	18	29	31	30	30	0	0	12	26	0	2	28	206	40.46	36.02	56.3%	37.0%	87.3%	51.6%
1989	11	11	29	30	31	0	0	18	17	6	0	0	153	30.05	26.83	41.9%	39.1%	67.0%	49.0%
1990	0	5	31	30	31	0	0	20	0	0	0	0	117	22.98	20.51	32.1%	27.7%	45.8%	37.8%
1991	0	2	29	30	31	30	31	31	13	16	0	0	213	41.84	37.35	58.4%	82.6%	43.4%	30.7%
1992	0	22	31	30	31	13	20	27	29	19	6	27	255	50.09	44.59	69.7%	75.5%	53.5%	64.2%
1993	29	28	31	30	31	5	0	0	10	0	0	0	164	32.21	28.76	44.9%	25.0%	85.8%	79.5%
1994	2	28	31	30	31	23	25	31	30	16	28	31	306	60.10	53.65	83.8%	84.8%	57.5%	37.5%
1995	30	28	31	30	31	0	5	31	27	28	13	10	264	51.85	46.29	72.3%	66.3%	98.6%	91.5%
1996	30	29	31	30	31	30	23	21	19	5	0	0	249	48.91	43.54	68.0%	70.1%	81.7%	72.4%
1997	7	28	31	30	31	4	12	29	5	0	1	28	206	40.46	36.12	56.4%	44.0%	59.9%	61.6%
1998	31	28	31	30	31	2	0	0	5	3	0	0	161	31.62	28.23	44.1%	22.3%	84.9%	63.0%
1999	0	26	31	30	31	1	13	27	14	30	26	12	241	47.34	42.26	66.0%	63.0%	55.7%	35.1%
2000	18	29	31	30	31	0	0	9	7	0	0	0	155	30.45	27.10	42.3%	25.5%	83.1%	71.6%
2001	0	0	0	26	31	3	16	27	30	5	0	0	138	27.11	24.20	37.8%	60.9%	26.9%	20.0%
2002	0	24	31	30	31	22	31	31	30	3	12	28	273	53.62	47.87	74.8%	80.4%	54.7%	54.0%
2003	31	28	31	30	31	25	31	31	21	8	2	16	285	55.98	49.97	78.1%	79.9%	90.1%	84.4%
2004	21	29	31	30	31	0	12	29	30	31	26	12	282	55.39	49.31	77.0%	72.3%	75.1%	75.4%
2005	30	28	31	30	31	30	29	31	9	7	27	21	304	59.71	53.30	83.3%	74.5%	88.7%	79.5%
2006	10	28	31	30	31	0	2	12	21	0	0	0	165	32.41	28.93	45.2%	35.9%	84.0%	77.8%
2007	0	26	31	30	31	20	21	20	14	8	0	1	202	39.68	35.42	55.3%	62.0%	55.7%	41.9%
2008	10	29	31	30	31	0	8	30	23	4	0	0	196	38.50	34.27	53.6%	52.2%	62.0%	58.7%
2009	0	19	31	30	31	30	31	31	25	1	0	11	240	47.14	42.08	65.8%	81.0%	52.4%	48.2%
2010	16	28	31	30	31	30	19	2	0	0	0	0	187	36.73	32.79	51.2%	44.6%	69.3%	72.6%
2011	0	20	31	30	31	0	9	31	25	26	20	3	226	44.39	39.63	61.9%	66.3%	52.8%	44.7%
2012	4	27	31	30	31	6	28	29	29	13	0	0	228	44.78	39.87	62.3%	73.9%	68.5%	64.8%
2013	0	14	31	30	31	25	31	31	28	3	0	0	224	44.00	39.28	61.4%	81.0%	50.0%	57.8%
MEANS																			
48YR	11	21	27	29	31	9	13	21	17	7	4	7	197	38.71	34.53	54.0%	52.9%	61.5%	54.0%
41YR	12	21	27	29	30	8	12	21	16	7	5	8	195	**38.27**	**34.14**	**53.4%**	51.1%	61.9%	53.4%

SUMMARY STATISTICS	CalYear	WetSeas	DrySeas	WatYear
No. of years used for stats	49	49	48	48
Years used for stats	'65-'13	'65-'13	'66-'13	'66-'13
# Yrs with WS duration > 70%	8	15	16	11
Annual Exceedance Frequency	16.3%	30.6%	33.3%	22.9%
Return Period (1-in-Nyrs)	6.1	3.3	3.0	4.4

Table 5-4. Lake Tohopekaliga water supply reliability for the WSmaxL scenario.

Lake TOH Water Supply Reliability Table for WSmaxL																Percent of Time WS Withdrawal			
	No. of Days per Month with Lake Toho WS Withdrawals at 99.0 cfs (64.0 MGD)												Days	Vol(kaf)	AvgMGD	CalYear	WetSeas	DrySeas	WatYear
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	May-Oct	Nov-Apr	May-Apr
1965	0	16	29	0	0	0	0	0	0	0	0	0	45	8.84	7.89	12.3%	0.0%		
1966	1	28	30	11	0	4	31	31	30	15	0	0	181	35.55	31.74	49.6%	60.3%	33.0%	19.2%
1967	0	16	15	0	0	0	0	0	0	0	0	0	31	6.09	5.44	8.5%	0.0%	14.6%	38.9%
1968	0	0	0	0	0	2	30	31	10	0	0	0	73	14.34	12.76	19.9%	39.7%	0.0%	0.0%
1969	0	0	22	26	22	0	0	0	6	27	21	22	146	28.68	25.60	40.0%	29.9%	33.0%	33.2%
1970	31	28	31	30	31	9	0	10	0	0	0	0	170	33.39	29.81	46.6%	27.2%	91.5%	59.7%
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	13.7%
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1974	0	0	0	0	0	0	0	29	30	4	0	0	63	12.37	11.05	17.3%	34.2%	0.0%	0.0%
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	17.3%
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1978	0	0	0	0	0	0	0	29	3	0	0	0	32	6.29	5.61	8.8%	17.4%	0.0%	0.0%
1979	4	28	31	30	31	1	0	0	27	7	0	0	159	31.23	27.88	43.6%	35.9%	58.5%	34.2%
1980	20	29	31	30	31	3	0	0	0	0	0	0	144	28.28	25.18	39.3%	18.5%	66.2%	48.1%
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	9.3%
1982	0	0	0	0	0	1	31	31	28	13	0	0	104	20.43	18.24	28.5%	56.5%	0.0%	0.0%
1983	7	28	31	30	31	13	20	31	28	13	7	15	254	49.89	44.54	69.6%	73.9%	59.9%	54.8%
1984	31	29	31	30	31	3	27	30	4	0	0	0	216	42.43	37.77	59.0%	51.6%	81.7%	76.2%
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	26.0%
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1988	5	28	31	16	0	0	0	0	0	0	0	0	80	15.71	13.99	21.9%	0.0%	37.6%	21.9%
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1991	0	0	0	0	0	0	0	30	13	16	0	0	59	11.59	10.35	16.2%	32.1%	0.0%	0.0%
1992	0	20	0	0	0	0	22	27	29	19	6	27	150	29.46	26.23	41.0%	52.7%	9.4%	21.6%
1993	29	28	31	30	31	5	0	0	0	0	0	0	154	30.25	27.00	42.2%	19.6%	85.8%	67.9%
1994	1	28	31	20	31	23	25	31	30	16	28	31	295	57.94	51.73	80.8%	84.8%	52.4%	31.8%
1995	30	28	31	30	31	0	5	31	27	28	13	10	264	51.85	46.29	72.3%	66.3%	98.6%	91.5%
1996	30	29	31	30	24	30	23	16	0	0	0	0	213	41.84	37.25	58.2%	50.5%	78.4%	72.4%
1997	0	0	0	0	0	0	0	0	2	0	0	21	23	4.52	4.03	6.3%	1.1%	0.0%	25.5%
1998	31	28	31	30	31	2	0	0	1	4	0	0	158	31.03	27.70	43.3%	20.7%	81.1%	39.2%
1999	0	26	26	0	0	0	8	7	14	30	26	12	149	29.27	26.13	40.8%	32.1%	24.5%	24.7%
2000	18	29	31	10	0	0	0	0	0	0	0	0	88	17.28	15.39	24.0%	0.0%	59.2%	50.5%
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
2002	0	25	2	0	0	0	7	31	30	3	0	21	119	23.37	20.87	32.6%	38.6%	12.7%	7.4%
2003	31	28	31	22	12	27	31	31	21	8	2	16	260	51.07	45.59	71.2%	70.7%	68.4%	55.9%
2004	21	29	23	0	0	0	0	0	16	31	26	12	158	31.03	27.63	43.2%	25.5%	42.7%	60.4%
2005	30	25	31	30	22	30	29	31	9	7	27	21	292	57.35	51.20	80.0%	69.6%	83.0%	55.1%
2006	10	28	31	30	4	0	0	0	0	0	0	0	103	20.23	18.06	28.2%	2.2%	71.2%	75.3%
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	1.1%
2008	0	0	0	0	0	0	0	4	23	4	0	0	31	6.09	5.42	8.5%	16.8%	0.0%	0.0%
2009	0	0	0	0	0	0	0	31	25	1	0	0	57	11.20	9.99	15.6%	31.0%	0.0%	8.5%
2010	0	11	31	30	31	30	19	2	0	0	0	0	154	30.25	27.00	42.2%	44.6%	48.6%	35.3%
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	22.5%
2012	0	0	0	0	0	0	0	0	29	13	0	0	42	8.25	7.34	11.5%	22.8%	0.0%	0.0%
2013	0	14	31	30	31	25	31	31	28	3	0	0	224	44.00	39.28	61.4%	81.0%	50.0%	32.1%
MEANS																			
48YR	7	12	14	10	9	4	7	11	9	5	3	4	96	18.80	16.77	26.2%	24.6%	27.9%	26.2%
41YR	8	13	14	10	9	4	7	11	9	6	4	5	100	**19.55**	**17.44**	**27.3%**	24.6%	29.7%	27.3%

SUMMARY STATISTICS	CalYear	WetSeas	DrySeas	WatYear
No. of years used for stats	49	49	48	48
Years used for stats	'65-'13	'65-'13	'66-'13	'66-'13
# Yrs with WS duration > 70%	4	4	8	4
Annual Exceedance Frequency	8.2%	8.2%	16.7%	8.3%
Return Period (1-in-Nyrs)	12.3	12.3	6.0	12.0

The UK-OPS Model will be used as a regulatory tool by water use permit applicants and the SFWMD to ensure permitting thresholds needed to protect fish and wildlife are not exceeded by future withdrawals. The UK-OPS Model also can be used as a planning tool to help potential users understand the reliability of a water source in the future. An independent scientific peer review was conducted on the UK-OPS Model in November 2019. The SFWMD received a positive peer review, and the reviewers confirmed the model was appropriately developed for its intended purpose. More information regarding the UK-OPS Model documentation report and the peer review are contained in **Appendices C** and **D**.

The Central Florida Water Initiative (2015) regional water supply plan developed by multiple state agencies, water management districts, and stakeholders indicated there will be increasing need for new water supplies in Central Florida to meet future growth and potentially augment existing sources within and beyond SFWMD boundaries in the coming years. Unreserved water, above that needed for protection of fish and wildlife in the UCOL reservation waterbodies, could be allocated to meet some of the water supply needs in Central Florida.

5.6 Summary

All unallocated surface water in the Kissimmee River and in the Headwaters Revitalization Lakes up to the stages in the HRS at S-65 (**Appendix B**, Figure B-7 and Table B-7) will be reserved. The Water Reservation is needed for protection of fish and wildlife and to ensure successful completion and implementation of the KRRP. The approach used to establish the WRLs within each UCOL waterbody was presented. The approach uses data from established hydrologic patterns for fish and wildlife and their respective habitats, which considers seasonality, duration, seasonal highs and lows, interannual variability, and other factors. The recession and ascension rates associated with the WRLs protect the breeding season and reproductive requirements of fish and wildlife, including listed species (e.g., Snail Kites).

Each reservation waterbody in the UCOL has a unique WRL based on historical inundation patterns and water management practices that fish and wildlife have adapted to since the regulation schedules were implemented. The WRLs show the water needed for fish and wildlife, while the water above this line is available for allocation to meet future water demands within Central Florida.

The UK-OPS Model was developed as a regulatory tool to ensure water needed for fish and wildlife is protected and the permitting threshold at the S-65 structure is not exceeded. Several model runs were presented to demonstrate model utility. The model is expected to be used by permittees and SFWMD regulatory staff in the future. The UK-OPS Model was evaluated by independent scientific peer reviewers.

The draft Water Reservation rules will prohibit new and increased uses of surface water from the Headwaters Revitalization Lakes and the Kissimmee River reservation waterbodies and limit the availability of future water use from UCOL reservation and contributing waterbodies. The draft Water Reservation rules will protect against future water use impacts and provide assurance that the water needed for fish and wildlife will be protected. Once in effect, the SFWMD's water use permitting program will use the Water Reservation rules and implementing criteria to ensure water use permit applicants do not withdraw reserved water.

LITERATURE CITED

Adamski, J.C. and E.E. German. 2004. *Hydrogeology and Quality of Ground Water in Orange County, Florida*. Water Resources Investigations Report 03-4257, United States Geological Survey, Tallahassee, FL.

Aday, D., J.D. Allan, B.L. Bedford, M.W. Collopy, and R. Prucha. 2009. *Scientific Peer Review of the Draft Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes*. Unpublished Report. South Florida Water Management District, West Palm Beach, Florida.

Aho, J.M., C.S. Anderson, and J.W. Terrell. 1986. *Habitat Suitability Index Models and Instream Suitability Curves: Redbreast Sunfish*. Biological Report 82(10.119). United States Fish and Wildlife Service, Washington, D.C.

Anderson, D.H. 2014a. *Interim hydrologic responses to Phase I of the Kissimmee River Restoration Project, Florida*. Restoration Ecology 22(3):353-366.

Anderson, D.H. 2014b. *Geomorphic responses to interim hydrology following Phase I of the Kissimmee River Restoration Project, Florida*. Restoration Ecology 22(3):367-375.

Anderson, D., S.G. Bousquin, G.E. Williams, and D.J. Colangelo. 2005. *Kissimmee River Restoration Studies, Volume II, Defining Success: Expectations for the Kissimmee River Restoration*. Technical Publication ERA 433. South Florida Water Management District, West Palm Beach, FL.

Arthington, A.H. 2012. *Environmental Flows: Saving Rivers in the Third Millennium*. University of California Press, Berkeley, CA.

Aucott, W.R. 1988. *Areal Variation in Recharge too and Discharge from the Floridan Aquifer System in Florida*. Water Resources Investigations Report 88-4057. United States Geological Survey, Tallahassee, FL.

Bain, M.B. 1992. *Study Designs and Sampling Techniques for Community-level Assessment of Large Rivers*, pp. 63-74. In: T.F. Cuffney and M.E. Gurtz (eds.), Proceedings of Biological Assessments in Large Rivers. North American Benthological Society Fifth Annual Technical Workshop, Louisville, KY.

Bartlett, R.D. and P.P. Bartlett. 1999. *A Field Guide to Florida Reptiles and Amphibians*. Gulf Publishing Company, Houston, TX.

Bennett, A.J. 1992. *Habitat Use by Florida Sandhill Cranes in the Okefenokee Swamp, Georgia*, pp. 121-129. In: D.A. Wood, Proceedings 1988 North American Crane Workshop, February 22-24, 1988, Lake Wales, Florida. Nongame Wildlife Program Technical Report 12, Florida Game and Fresh Water Fish Commission, Tallahassee, FL.

Bonvechio, T.F. and M.S. Allen. 2005. *Relations between hydrologic variables and year-class strength of sportfish in eight Florida waterbodies*. Hydrobiologia 532:193-207.

Bousquin, S.G. and J. Colee. 2014. *Interim responses of littoral river channel vegetation to reestablished flow after Phase I of the Kissimmee River Restoration Project*. Restoration Ecology 22(3):388-396.

Bousquin, S.G., D.H. Anderson, D.J. Colangelo, and G.E. Williams. 2005a. *Introduction to Baseline Studies of the Channelized Kissimmee River*. In: S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo (eds.), Kissimmee River Restoration Studies, Volume I, Establishing a Baseline: Pre-Restoration Studies of the Channelized Kissimmee River. Technical Publication ERA 432. South Florida Water Management District, West Palm Beach, FL.

Bousquin, S.G., D.H. Anderson, G.E. Williams, and D.J. Colangelo (eds.). 2005b. *Kissimmee River Restorations Studies, Volume I, Establishing a Baseline: Pre-Restoration Studies of the Channelized Kissimmee River*. Technical Publication ERA 432. South Florida Water Management District, West Palm Beach, FL.

Bousquin, S.G., D.H. Anderson, D.J. Colangelo, J.L. Glenn III, J.W. Koebel Jr., and G.E. Williams. 2007. *Phase I of the Kissimmee River Restoration Project: Initial River Channel Responses*, pp. 1-10. In: K.C. Kabbes (ed.), Proceedings of the 2007 World Environmental and Water Resource Congress: Restoring Our Natural Habitat. American Society of Civil Engineers, Tampa, FL.

Bousquin, S.G., D.H. Anderson, M.D. Cheek, D.J. Colangelo, L. Dirk, J.L. Glenn, B.L. Jones, J.W. Koebel, J.A. Mossa, and J. Valdes. 2009. *Chapter 11: Kissimmee Basin*. In: 2009 South Florida Environmental Report, Volume I: The South Florida Environment. South Florida Water Management District, West Palm Beach, FL.

Brenner, M., M.W. Binford, and E.S. Deevey. 1990. *Lakes*, pp. 364-391. In: R.L. Myers and J.J. Ewel (eds.), Ecosystems of Florida. University of Central Florida Press, Orlando, FL.

Buehler, D.A. 2000. *Bald Eagle (*Haliaeetus leucocephalus*)*, Number 506. In: A. Poole and F. Gill (eds.), The Birds of North America. The Birds of North America, Inc., Philadelphia, PA.

Carlander, K.D. 1977. *Handbook of Freshwater Fish Biology, Volume Two*. Iowa State University Press, Ames, IA.

Carnal, L.L. and S.G. Bousquin. 2005. *Chapter 10: Areal Coverage of Floodplain Plant Communities in Pool C of the channelized Kissimmee River*. In: S.G. Bousquin, D.H. Anderson, G.E. Williams, and D.J. Colangelo (eds.), Kissimmee River Restoration Studies, Volume I, Establishing a Baseline: Pre-Restoration Studies of the Channelized Kissimmee River. Technical Publication ERA 432. South Florida Water Management District, West Palm Beach, FL.

Cattau, C., W. Kitchens, B. Reichert, A. Bowling, A. Hotaling, C. Zweig, J. Olbert, K. Pias, and J. Martin. 2008. *Demographic, movement, and habitat studies of the endangered snail kite in response to operational plans in Water Conservation Area 3A*. United States Geological Survey, Florida Cooperative Fish and Wildlife Research Unit, University of Florida, Gainesville, FL.

Cattau, C., B. Reichert, W. Kitchens, R. Fletcher Jr., J. Olbert, K. Pias, E. Robertson, R. Wilcox, and C. Zweig. 2012. *Snail Kite Demography Annual Report*. United States Geological Survey, Florida Cooperative Fish and Wildlife Research Unit, University of Florida, Gainesville, FL.

Central Florida Water Initiative. 2015. *Central Florida Water Initiative Regional Water Supply Plan: Volume I. Planning Document*.

Cheek, M.D., G.E. Williams, S.G. Bousquin, J. Colee, and S.L. Melvin. 2014. *Interim Response of Wading Birds (Pelecaniformes and Ciconiiformes) and Waterfowl (Anseriformes) to the Kissimmee River Restoration Project, Florida, U.S.A*. Restoration Ecology 22(3):426-434.

Colangelo, D.J. 2014. *Interim response of dissolved oxygen to reestablished flow in the Kissimmee River, Florida, U.S.A*. Restoration Ecology 22(3):376-387.

Cooke, G.D., E.B. Welch, S.A. Peterson, and P.R. Newroth. 1993. *Restoration and management of lakes and reservoirs*. Second edition. Lewis Publishers, Boca Raton, Florida.

Darby, P.C. and H.F. Percival. 2000. *Dry Down Tolerance of the Florida Apple Snail (*Pomacea paludosa *Say): Effects of Age and Season*. Research Work Order 182, United States Geological Survey, Washington, D.C.

Darby, P.C., R.E. Bennetts, J.D. Croop, P.L. Valentine-Darby, and W.M. Kitchens. 1999. *A comparison of sampling techniques for quantifying abundance of the Florida apple snail (*Pomacea paludosa*, Say)*. Journal of Molluscan Studies 65:195-208.

Darby, P.C., R.E. Bennetts, S.J. Miller, and H.F. Percival. 2002. *Movements of Florida apple snails in relation to water levels and drying events*. Wetlands 22:489-498.

Darby, P., R. Bennetts, and F. Percival. 2008. *Dry down impacts on apple snail (*Pomacea paludosa*) demography: Implications for wetland water management*. Wetlands 28:204-214.

Delany, M.F. 1990. *Late summer diet of juvenile American alligators*. Journal of Herpetology 24:418-421.

Delany, M.F. and C.L. Abercrombie. 1986. *American alligator food habits in north central Florida*. Journal of Wildlife Management 50:348-353.

Department of the Army and SFWMD. 1994. *Project Cooperation Agreement between the Department of the Army and South Florida Water Management District for Construction of the Kissimmee River, Florida, Project*. Department of the Army, Washington, D.C. and South Florida Water Management District, West Palm Beach, FL. March 22, 1994.

Fan, A. 1986. *A routing model for the upper Kissimmee Chain of Lakes*. Technical Publication 86-5, DRE-225. South Florida Water Management District, West Palm Beach, FL.

Fletcher, R., C. Poli, E. Robertson, B. Jeffrey, S. Dudek, and B. Reichert. 2017. *Snail kite demography 2016 annual report*. United States Geological Survey, Florida Cooperative Fish and Wildlife Research Unit, University of Florida, Gainesville, FL.

Florida Department of Environmental Protection. 1998. *Lake Kissimmee State Park Unit Management Plan*. Florida Department of Environmental Protection, Tallahassee, FL.

Florida Division of Administrative Hearings. 2006. *Association of Florida Community Developers, et al. versus Department of Environmental Protection, et. al.*, Division of Administrative Hearings Case Number 04-000880, Final Order February 24, 2006, affirmed 943 So. 2d 989 (Florida Fourth District Court of Appeals 2006). Available at: https://www.doah.state.fl.us/ALJ/SearchDOAH (search on Recommended Order Date 2/24/2006).

Florida Game and Fresh Water Fish Commission. 1957. *Recommended Program for Kissimmee River Basin*. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.

Frederick, P.C. and M.W. Collopy. 1989a. *The role of predation in determining reproductive success of colonially nesting wading birds in the Florida Everglades*. The Condor 91:860-867.

Frederick, P.C. and M.W. Collopy. 1989b. *Nesting success of five ciconiiform species in relation to water conditions in the Florida Everglades*. The Auk 106:625-634.

FWC. 2003. *Florida's Breeding Bird Atlas: A Collaborative Study of Florida's Birdlife*. Florida Fish and Wildlife Conservation Commission.

FWC. 2008. *Bald Eagle (*Haliaeetus leucocephalus*) Management Plan*. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL.

FWC. 2013. *Florida's Threatened and Endangered Species*. Division of Habitat and Species Conservation, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL.

Gerking, S.D. 1994. *Feeding Ecology of Fish*. Academic Press, New York, NY.

Gladden, J.E. and L.A. Smock. 1990. *Macroinvertebrate distribution and production on the floodplains of two lowland headwater streams*. Freshwater Biology 24:533-545.

Goodwin, T.M. and W.R. Marion. 1978. *Aspects of the nesting ecology of American alligators (*Alligator mississippensis*) in north-central Florida*. Herpetologica 34:43-47.

Havens, K.E., D. Fox, S. Gornak, and C. Hanlon. 2005. *Aquatic vegetation and largemouth bass population responses to water-level variations in Lake Okeechobee, Florida (USA)*. Hydrobiologia 539:225-237.

Hill, N.M., P.A. Keddy, and I.C. Wisheu. 1998. *A hydrological model for predicting the effects of dams on shoreline vegetation of lakes and reservoirs*. Environmental Management 22:723-736.

Holcomb, D. and W. Wegener. 1972. *Hydrophytic Changes Related to Lake Fluctuation as Measured by Point Transects*. Proceedings of Annual Conference of the Southeastern Conference of Game and Fish Commissioners 25:570-583.

Hoyer, M.V. and D.E. Canfield Jr. 1990. *Limnological factors influencing bird abundance and species richness on Florida lakes*. Lake and Reservoir Management 6:132-141.

Hoyer, M.V. and D.E. Canfield Jr. 1994. *Bird abundance and species richness on Florida lakes: Influence of trophic status, lake morphology, and aquatic macrophytes*. Hydrobiologia 297/280:107-119.

Hulon, M., A. Furukawa, J. Buntz, J. Sweatman, and C. Mich. 1998. *Lake Jackson wildlife islands*. Aquatics 20:4-9.

Johnson, K.G., M.S. Allen, and K.E. Havens. 2007. *A review of littoral vegetation, fisheries, and wildlife response to hydrologic variation at Lake Okeechobee*. Wetlands 27:110-126.

Jordan, F. and A. Arrington. 2014. *Piscivore responses to enhancement of the channelized Kissimmee River, Florida, U.S.A*. Restoration Ecology 22(3):418-425.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. *The flood pulse concept in river-floodplain systems*, pp. 110-127. In: Proceedings of the International Large River Symposium, Canadian Special Publication of Fisheries and Aquatic Sciences.

Karr, J.R., K.D. Fausch, P.L. Andermeier, P.R. Yant, and I.J. Schlosser. 1986. *Assessing Biological Integrity in Running Waters: A Method and its Rationale*. Special Publication 5. Illinois Natural History Survey, Illinois Department of Natural Resources, Springfield, IL. September 1986.

Karr, J.R., H. Stefan, A.C. Benke, R.E. Sparks, M.W. Weller, J.V. McArthur, and J.H. Zar. 1992. *Design of a Restoration Evaluation Program*. South Florida Water Management District, West Palm Beach, FL.

Keddy, P.A. 2000. *Wetland Ecology: Principles and Conservation*. Cambridge University Press, Cambridge, UK.

Keddy, P. and L.H. Fraser. 2000. *Four general principles for the management of conservation of wetlands in large lakes: The role of water levels, nutrients, competitive hierarchies and centrifugal organization*. Lake & Reservoir: Research and Management 5:177-185.

Koebel, J.W., Jr. 1995. *A Historical Perspective on the Kissimmee River Restoration Project*. Restoration Ecology 3:149-159.

Koebel, J.W. and S. Bousquin. 2014. The *Kissimmee River Restoration Project and Evaluation Program, Florida, U.S.A*. Restoration Ecology 22(3):345-352.

Koebel, J.W., S.G. Bousquin, and J. Colee. 2014. *Interim responses of benthic and snag-dwelling macroinvertebrates to reestablished flow and habitat structure in the Kissimmee River, Florida, U.S.A*. Restoration Ecology 22(3):409-417.

Koebel, J.W., Jr., S.G. Bousquin, D.H. Anderson, Z. Welch, M.D. Cheek, H. Chen, R.T. James, J. Zhang, B. Anderson, R. Baird, T. Beck, A. Brunell, D. Colangelo, T. Coughlin, K. Lawrence, and C. Mallison. 2016. *Chapter 9: Kissimmee River Restoration and Basin Initiatives*. In: 2016 South Florida Environmental Report – Volume I. South Florida Water Management District, West Palm Beach, FL.

Koebel, J.W., Jr., S.G. Bousquin, D.H. Anderson, M.D. Cheek, C. Carroll, H. Chen, C. Hanlon, Z. Welch, B. Anderson, L. Spencer, T. Beck, and A. Brunell. 2019. *Chapter 9: Kissimmee River Restoration and Basin Initiatives*. In: 2019 South Florida Environmental Report – Volume I. South Florida Water Management District, West Palm Beach, FL.

Koebel, J.W., S.G. Bousquin, D.H. Anderson, M.D. Cheek, C. Carroll, H. Chen, B. Anderson, T. Beck, and A. Brunell. 2020. *Chapter 9: Kissimmee River Restoration and Basin Initiatives*. In: 2020 South Florida Environmental Report – Volume I. South Florida Water Management District, West Palm Beach, FL.

Loftin, M.K., L.A. Toth, and J.T.B. Obeysekera (eds.). 1990a. *Proceedings of the Kissimmee River Restoration Symposium, October 1988, Orlando, Florida*. South Florida Water Management District, West Palm Beach, FL.

Loftin, M.K., L.A. Toth, and J.T.B. Obeysekera. 1990b. *Kissimmee River Restoration Alternative Plan Evaluation and Preliminary Design Report*. South Florida Water Management District, West Palm Beach, FL.

Loucks, D.P., D.A. Chin, and R.H. Prucha. 2008. *Kissimmee Basin Modeling and Operations Study – Peer Review Panel Task 3 Report*. Submitted to South Florida Water Management District, West Palm Beach, FL.

Mallison, C. 2009. Kissimmee Chain of Lakes. Using: ArcGIS. Redlands, CA: Environmental Systems Research Institute, Inc.

Mallison, C. 2016. Kissimmee Chain of Lakes. Using: ArcGIS. Redlands, CA: Environmental Systems Research Institute, Inc.

McEwan, L.C. and D.H. Hirth. 1980. *Food habits of the bald eagle in north-central Florida*. The Condor 82:229-231.

Miller, S.J. 1990. *Kissimmee River Fisheries – A Historical Perspective*, pp. 31-42. In: M.K. Loftin, L.A. Toth, and J. Obeysekera (eds.), Proceedings of the Kissimmee River Restoration Symposium, October 1988, Orlando, Florida. South Florida Water Management District, West Palm Beach, FL.

Moyer, E.J., M.W. Hulon, R.S. Butler, D.C. Arwood, C. Michael, and C.A. Harris. 1987. *State of Florida Game and Fresh Water Fish Commission 1987 Kissimmee Chain of Lakes Studies Completion Report for Study No. I Lake Tohopekaliga Investigations*. Florida Game and Freshwater Fish Commission, Tallahassee, FL.

Muench, A.M. 2004. *Aquatic Vertebrate Usage of Littoral Habitat Prior to Extreme Habitat Modification in Lake Tohopekaliga, Florida*. Master of Science thesis, University of Florida, Gainesville, FL.

National Audubon Society. 1936-1959. *Audubon Warden Field Reports*. Everglades National Park, South Florida Research Center, Homestead, FL.

Newsom, J.D., T. Joanen, and R.J. Howard. 1987. *Habitat Suitability Index Models: American Alligator*. Biological Report 82(10.136). United States Fish and Wildlife Service, United States Department of the Interior, Lafayette, LA.

Perrin, L.S., M.J. Allen, L.A. Rowse, F. Montalbano, K.J. Foote, and M.W. Olinde. 1982. *A Report on Fish and Wildlife Studies in the Kissimmee River Basin and Recommendations for Restoration*. Florida Fish and Wildlife Conservation Commission, Okeechobee, FL.

Poff, N.L. and J.D. Allan. 1995. *Functional organization of stream fish assemblages in relation to hydrologic variability*. Ecology 76:606-627.

Poff, N.L., J.D. Allen, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. *The natural flow regime: A paradigm for river conservation and restoration*. Bioscience 47:769-784.

Poole, A. (ed.). 2008. *The Birds of North America Online.* Cornell Lab of Ornithology, Ithaca, NY. Available online at http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna.

Pranty, B. 2002. *The Important Bird Areas of Florida: 2000–2002*. Audubon of Florida. Available online at http://www.audubon.org/bird/iba/florida.

Preble, G.H. 1945. *A canoe expedition into the Everglades in 1842*. Tequesta 5(1945):30-51.

Reese, R. and E. Richardson. 2008. *Synthesis of the Hydrogeologic Framework of the Floridan Aquifer System and Delineation of a Major Avon Park Permeable Zone in Central and Southern Florida*. Scientific Investigation Report 2007-5207. United States Geological Survey, Washington, D.C.

Savino, J.F. and R.A. Stein. 1982. *Predator-prey interactions between largemouth bass and bluegills as influenced by simulated, submersed vegetation*. Transactions of the American Fisheries Society 111:255-347.

Scheaffer, W.A. and J.G. Nickum. 1986. *Backwater areas as nursery habitats for fishes in Pool 13 of the Upper Mississippi River*. Hydrobiologia 136:131-140.

SFWMD. 2000. *Kissimmee Basin Water Supply Plan*. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2007. *2005–2006 Kissimmee Basin Water Supply Plan Update*. Water Supply Department, South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2008. *Lower East Coast Water Supply Plan – 2008*. Final Order on Amendment to Appendix H. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2009. *Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes-Draft for Scientific Peer Review Panel*. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2015a. *Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes-DRAFT*. South Florida Water Management District, West Palm Beach, FL. March 2015.

SFWMD. 2015b. *Applicant's Handbook for Water Use Permit Applications within the South Florida Water Management District.* South Florida Water Management District, West Palm Beach, FL. September 7, 2015.

SFWMD. 2018. *2018 Lower East Coast Water Supply Plan Update*. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2019. *2019 South Florida Environmental Report, Volume 1, Chapter 8B*. South Florida Water Management District, West Palm Beach, FL.

Shaw, J.E. and S.M. Trost. 1984. *Hydrogeology of the Kissimmee Planning Area, South Florida Water Management District*. Technical Publication 84-1 (DRE-188). South Florida Water Management District, West Palm Beach, FL.

Snyder, N.F.R., S.R. Beissinger, and R.E. Chandler. Reproduction and demography of the Florida Everglade (snail) kite. 1989. The Condor 91:300-316.

Spencer, L. and S. Bousquin. 2014. *Interim responses of floodplain wetland vegetation to Phase I of the Kissimmee River Restoration Project: Comparisons of vegetation maps from five periods in the river's history*. Restoration Ecology 22(3):397-408.

Stuber, R.J., G. Gebhart, and O.E. Maughan. 1982a. *Habitat Suitability Index Models: Bluegill*. FWS/OBS-82/10.8. United States Fish and Wildlife Service, Washington, D.C.

Stuber, R.J., G. Gebhart, and O.E. Maughan. 1982b. *Habitat Suitability Index Models: Largemouth Bass*. FWS/OBS-82/10.16. United States Fish and Wildlife Service, Washington, D.C.

Stys, B. 1997. *Ecology of the Florida Sandhill Crane*. Nongame Wildlife Technical Report Number 15. Florida Game and Freshwater Fish Commission, Tallahassee, FL.

Sykes, P.W., Jr., J.A. Rodgers Jr., and R.E. Bennetts. 1995. *Snail Kite (*Rostrhamus sociabilis*)*. In: A. Poole (ed.), The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, NY. Available online at http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna/species/171.

Tacha, T.C., S.A. Nesbit, and P.A. Vohs. 1992. *Sandhill Crane. Number 31*. In: A. Poole, P. Stettenheim, and F. Gills (eds.), The Birds of North America. Academy of Natural Sciences, Philadelphia, PA and American Ornithologists' Union, Washington, D.C.

Tarboton, K.M., M.M. Irizarry-Ortiz, D.P. Loucks, S.M. Davis, and J.T. Obeysekera. 2004. *Habitat Suitability Indices for Evaluating Water Management Alternatives*. South Florida Water Management District. West Palm Beach, FL.

Tennant, A. 1997. *A Field Guide to the Snakes of Florida*. Gulf Publishing Company, Houston, TX.

Toland, B. 1999. *Nesting success and productivity of Florida sandhill cranes on natural and developed sites in southeast Florida*. Florida Field Naturalist 27:10-13.

Toth, L.A. 1990. *Impacts of Channelization on the Kissimmee River Ecosystem*, pp. 47-56. In: M.K. Loftin, L.A. Toth, and J. Obeysekera (eds.), Proceedings of the Kissimmee River Restoration Symposium, October 1988, Orlando, Florida. South Florida Water Management District, West Palm Beach, FL.

Toth, L.A. 1991. *Environmental Responses to the Kissimmee River Demonstration Project*. Technical Publication 91-02. South Florida Water Management District, West Palm Beach, FL.

Toth, L.A. 1993. *The ecological basis of the Kissimmee River Restoration Plan*. Florida Scientist 56:25-51.

Toth, L.A., D.A. Arrington, M.A. Brady, and D.A. Muszick. 1995. *Conceptual evaluation of factors potentially affecting restoration of habitat structure within the channelized Kissimmee River ecosystem*. Restoration Ecology 3:160-180.

Toth, L.A., J.W. Koebel Jr., A.G. Warne, and J. Chamberlain. 2002. *Chapter 6: Implications of Reestablishing Prolonged Flood Pulse Characteristics of the Kissimmee River and Floodplain Ecosystem*, pp. 191-221. In: B.A. Middleton (ed.), Flood Pulsing in Wetlands: Restoring the Natural Hydrological Balance. John Wiley & Sons, Inc., New York, NY.

Trexler, J.C. 1995. *Restoration of the Kissimmee River: A conceptual model of past and present fish communities and its consequences for evaluating restoration success*. Restoration Ecology 3:195-210.

Turner, R.L. 1996. *Use of stems of emergent vegetation for oviposition by the Florida apple snail (*Pomacea paludosa*), and implications for marsh management*. Florida Scientist 59:34-49.

USACE. 1985. *Central and Southern Florida, Kissimmee River, Florida Final Feasibility Report and Environmental Impact Statement*. United States Army Corps of Engineers, Jacksonville, FL.

USACE. 1991. *Central and Southern Florida Project Final Integrated Feasibility Report and Environmental Impact Statement Environmental Restoration Kissimmee River, Florida*. United States Army Corps of Engineers, Jacksonville, FL. December 1991.

USACE. 1994. *Master Water Control Manual for the Kissimmee River - Lake Istokpoga Basin (Draft).* United States Army Corps of Engineers, Jacksonville, FL.

USACE. 1996. *Central and Southern Florida Project Kissimmee River Headwaters Revitalization Project Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement*. United States Army Corps of Engineers, Jacksonville, FL. January 1996.

USFWS. 1958. *A Detailed Report of the Fish and Wildlife Resources in Relation to the Corps of Engineers' Plan of Development Kissimmee River Basin, Florida.* United States Fish and Wildlife Service, Vero Beach, FL.

USFWS. 1994. *Fish and Wildlife Coordination Act Report on Kissimmee Headwater Lakes Revitalization Plan*. United States Fish and Wildlife Service, Washington, D.C.

USFWS. 1999. *South Florida multi-species recovery plan.* Atlanta, Georgia, USA: United States Fish and Wildlife Service, Washington, D.C.

USFWS. 2002. 2001 *National Survey of Fishing, Hunting, and Wildlife-associated Recreation: National Overview*. United States Fish and Wildlife Service, Washington, D.C.

Warne, A.G., L.A. Toth, and W.A White. 2000. *Drainage-basin-scale Geomorphic Analysis to Determine Reference Conditions for Ecological Restoration – Kissimmee River, Florida*. GSA Bulletin 112:884-899.

Welch, Z.C. 2004. *Littoral Vegetation of Lake Tohopekaliga: Community Descriptions Prior to a Large-scale Fisheries Habitat-enrichment Project*. Master of Science Thesis, University of Florida, Gainesville, FL.

Welcomme, R.L. 1979. *Fisheries Ecology of Floodplain Rivers*. Longman Group Limited, London, United Kingdom.

Welcomme, R.L. and D. Hagborg. 1977. *Towards a model of a floodplain fish population and its fishery*. Environmental Biology of Fishes 2:7-24.

Weller, M.W. 1995. *Use of two waterbird guilds as evaluation tools for the Kissimmee River restoration*. Restoration Ecology 3:211-224.

White, W.A. 1970. *The Geomorphology of the Florida Peninsula*. Geological Bulletin No. 51. Florida Department of Natural Resources, Tallahassee, FL.

White, L., P.C. Frederick, M.B. Main, and J.A. Rodgers Jr. 2005. *Nesting Island Creation for Wading Birds*. Circular 1473. Wildlife Ecology and Conservation Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL.

Wilcox, D.A. and S.J. Nichols. 2008. *The effects of water-level fluctuations on vegetation in a Lake Huron wetland*. Wetlands 28(2):487-501.

Williams, L.E., Jr. 1978. *Florida Sandhill Crane*, pp. 36-37. In: H.W. Kale, II (ed.), Rare and Endangered Biota of Florida, Volume 2: Birds.

Williams, G.E. and S.L. Melvin. 2005. *Expectation 24: Density of Long-legged Wading Birds on the Floodplain*. In: D.H. Anderson, S.G. Bousquin, G.E. Williams, and D.J. Colangelo (eds.), Kissimmee River Restoration Studies, Volume II, Defining Success: Expectations for the Kissimmee River Restoration. Technical Publication ERA 433. South Florida Water Management District, West Palm Beach, FL.

Williams, V.P., D.E. Canfield Jr, M.M. Hale, W.E. Johnson, R.S. Kautz, J.T. Krummrich, F.H. Langford, K. Langland, S.P. McKinney, D.M. Powell, and P.L. Shafland. 1985. *Lake Habitats and Fishery Resources of Florida*, pp. 43-119. In: W. Seaman Jr. (ed.), Florida Aquatic Habitat and Fishery Resources. Florida Chapter of the American Fisheries Society, Eustis, FL.

Winemiller, K.O. and D.B. Jepsen. 1998. *Effects of seasonality and fish movement on tropical river food webs*. Journal of Fish Biology 53(Supplement A):267-296.

Woodward, A.R., T.C. Hines, C.L. Abercrombie, and J.D. Nichols. 1987. *Survival of young American alligators on a Florida Lake*. Journal of Wildlife Management 51:931-937.

Wullschleger, J.G., S.J. Miller, and L.J. Davis. 1990a. *An Evaluation of the Effects of the Restoration Demonstration Project on Kissimmee River Fishes*, pp. 67-81. In: M.K. Loftin, L.A. Toth, and J. Obeysekera (eds.), Proceedings of the Kissimmee River Restoration Symposium, October 1988, Orlando, Florida. South Florida Water Management District, West Palm Beach, FL.

Wullschleger, J.G., S.J. Miller, and L.J. Davis. 1990b. *A Survey of Fish Communities in Kissimmee River Oxbows Scheduled for Phase II Restoration*, pp. 143-148. In: M.K. Loftin, L.A. Toth, and J. Obeysekera (eds.), Proceedings of the Kissimmee River Restoration Symposium, October 1988, Orlando, Florida. South Florida Water Management District, West Palm Beach, FL.

APPENDIX A: WATER RESERVATION WATERBODIES AND CONTRIBUTING AREAS

For the proposed Kissimmee River and Chain of Lakes Water Reservations, a reservation waterbody contains the fish and wildlife protected by the Water Reservation rules, and is where fish and wildlife roost, feed and forage, breed and nest, or shelter. These needs were considered when determining the quantity of water needed to protect fish and wildlife in the Kissimmee River and Chain of Lakes.

Many reservation waterbodies are connected directly or indirectly to other natural or man-made surface waterbodies that contribute water to reservation waterbodies but are not considered reservation waterbodies themselves. Draft amendments to Rule 40E-10.021, Florida Administrative Code, define a contributing waterbody as “all wetlands and other surface waters, including canals and ditches, that contribute surface water to a reservation waterbody.” Contributing waterbodies continuously or intermittently provide water needed to maintain an adequate hydrologic regime for the protection of fish and wildlife in the reservation waterbodies to which they are connected.

This appendix lists (**Table A-1**) and depicts (**Figures A-1** through **A-9**) the reservation and contributing waterbodies of the proposed Kissimmee River and Chain of Lakes Water Reservations. The waterbodies are further described and discussed in the main report and other appendices and in draft implementation rules for Section 3.11.5 of the *Applicant’s Handbook for Water Use Permit Applications within the South Florida Water Management District* (Applicant’s Handbook; SFWMD 2015) and Chapter 40E-10, Florida Administrative Code, that are pertinent to the Kissimmee River and Chain of Lakes Water Reservations. Other wetlands and surface waters not specifically included in the Kissimmee River and Chain of Lakes Water Reservations are protected to a “no harm” standard under Section 3.3 of the Applicant’s Handbook (SFWMD 2015).

Table A-1. Kissimmee River and Chain of Lakes Water Reservations waterbody list, as shown in **Figures A-1** through **A-9**, sorted by watershed and map identification number.

Waterbody Number	Waterbody Name	Waterbody Type
Lakes Hart-Mary Jane		
1	Lake Whippoorwill	Reservation
2	Whippoorwill Canal	Reservation
3	Lake Hart	Reservation
4	C-29 Canal	Reservation
5	Lake Mary Jane	Reservation
6	C-29A Canal north of S-62	Reservation
7	C-30 Canal north of S-57	Reservation
Lake Myrtle-Preston-Joel		
8	C-30 Canal south of S-57	Reservation
9	Lake Myrtle	Reservation
10	Myrtle/Preston Canal	Reservation
11	Lake Preston	Reservation
12	C-32B Canal	Reservation
13	Lake Joel	Reservation
14	C-32C Canal north of S-58	Reservation

Waterbody Number	Waterbody Name	Waterbody Type
East Lake Tohopekaliga		
15	C-29A Canal south of S-62	Reservation
16	Ajay Lake	Reservation
17	C-29B Canal	Reservation
18	Fells Cove	Reservation
19	Boggy Creek	Contributing
20	East Lake Tohopekaliga	Reservation
21	Runnymede Canal	Reservation
22	Lake Runnymede	Reservation
23	C-31 Canal northeast of S-59	Reservation
Lake Tohopekaliga		
24	C-31 Canal southwest of S-59	Reservation
25	Fish Lake	Contributing
26	Bass Slough	Contributing
27	Partin Canal	Contributing
28	Mill Slough	Contributing
29	East City Ditch	Contributing
30	West City Ditch	Contributing
31	Shingle Creek including Western Branch (West Shingle Creek)	Contributing
32	Lake Tohopekaliga	Reservation
33	WPA Canal	Contributing
34	Gator Bay Branch	Contributing
35	Fanny Bass Ditch	Contributing
36	Fanny Bass Pond	Contributing
37	Drawdy Bay Ditch	Contributing
Alligator Chain of Lakes		
38	C-33 Canal north of S-60	Reservation
39	Alligator Lake	Reservation
40	Brick Canal	Reservation
41	Brick Lake	Reservation
42	Buck Slough	Contributing
43	Buck Lake	Contributing
44	Live Oak Lake	Reservation
45	Live Oak Canal	Reservation
46	Sardine Lake	Reservation
47	Sardine Canal	Reservation
48	C-32G Canal	Reservation
49	Lake Lizzie	Reservation
50	C-32F Canal	Reservation
51	Lake Center	Reservation
52	Center-Coon Canal	Reservation
53	Coon Lake	Reservation
54	C-32D Canal	Reservation
55	Trout Lake	Reservation
56	C-32C Canal south of S-58	Reservation

Waterbody Number	Waterbody Name	Waterbody Type
Lake Gentry		
57	C-34 Canal north of S-63	Reservation
58	Lake Gentry	Reservation
59	Big Bend Swamp	Contributing
60	Big Bend Swamp Canal/Gentry Ditch	Contributing
61	C-33 Canal south of S-60	Reservation
Headwaters Revitalization Lakes		
62	C-35 Canal south of S-61	Reservation
63	Cypress Lake	Reservation
64	C-34 Canal south of S-63A	Reservation
65	C-34 Canal north of S-63A	Reservation
66	Lake Russell	Contributing
67	Lower Reedy Creek south of REED40	Contributing
68	Upper Reedy Creek north of REED40	Contributing
69	Bonnet Creek	Contributing
70	C-36 Canal	Reservation
71	Lake Hatchineha	Reservation
72	Lake Marion Creek	Contributing
73	Lake Marion	Contributing
74	Catfish Creek	Contributing
75	Lake Pierce	Contributing
76	C-37 Canal	Reservation
77	Lake Kissimmee	Reservation
78	Zipprer Canal east of G-103	Reservation
79	Zipprer Canal west of G-103	Contributing
80	Lake Rosalie	Contributing
81	Weohyakapka Creek	Contributing
82	Lake Weohyakapka	Contributing
83	Tiger Lake	Reservation
84	Tiger Creek	Reservation
85	Otter Slough	Contributing
86	Jackson Canal south of G-111	Reservation
87	Jackson Canal north of G-111	Contributing
88	Lake Jackson	Contributing
89	Parker Hammock Slough	Contributing
90	Lake Marian	Contributing
91	Fodderstack Slough	Contributing
92	No Name Slough	Contributing
Kissimmee River Pool A*		
93	Buttermilk Slough	Contributing
94	Packingham Slough	Contributing
95	Ice Cream Slough	Contributing
96	Blanket Bay Slough	Contributing
97	Armstrong Slough	Contributing

Waterbody Number	Waterbody Name	Waterbody Type
Kissimmee River Pool B/C/D*		
98	Tick Island Slough	Contributing
99	Pine Island Slough	Contributing
100	Sevenmile Slough	Contributing
101	Starvation Slough	Contributing
102	Oak Creek	Contributing
103	Ash Slough	Contributing
104	Gore Slough	Contributing
105	Fish Slough	Contributing
106	Cypress Slough	Contributing
107	Istokpoga Canal and floodplain east of S-67	Reservation
108	Istokpoga Creek west of S-67	Contributing
Kissimmee River Pool E*		
109	C-38 Canal and remnant river channels from S-65 to S-65E	Reservation
Kissimmee River Pools A-E*		
110	Kissimmee River and floodplain between S-65 and S-65D	Reservation

* Currently, the Kissimmee River is divided into three pools (A, B/C/D, and E) by a series of combined locks and spillways. The water level in each pool is regulated according to an interim regulation schedule.

Disclaimer: Features shown in the following figures are cartographic representations and do not supersede legal descriptions or other regulatory criteria used to define such features on the ground.

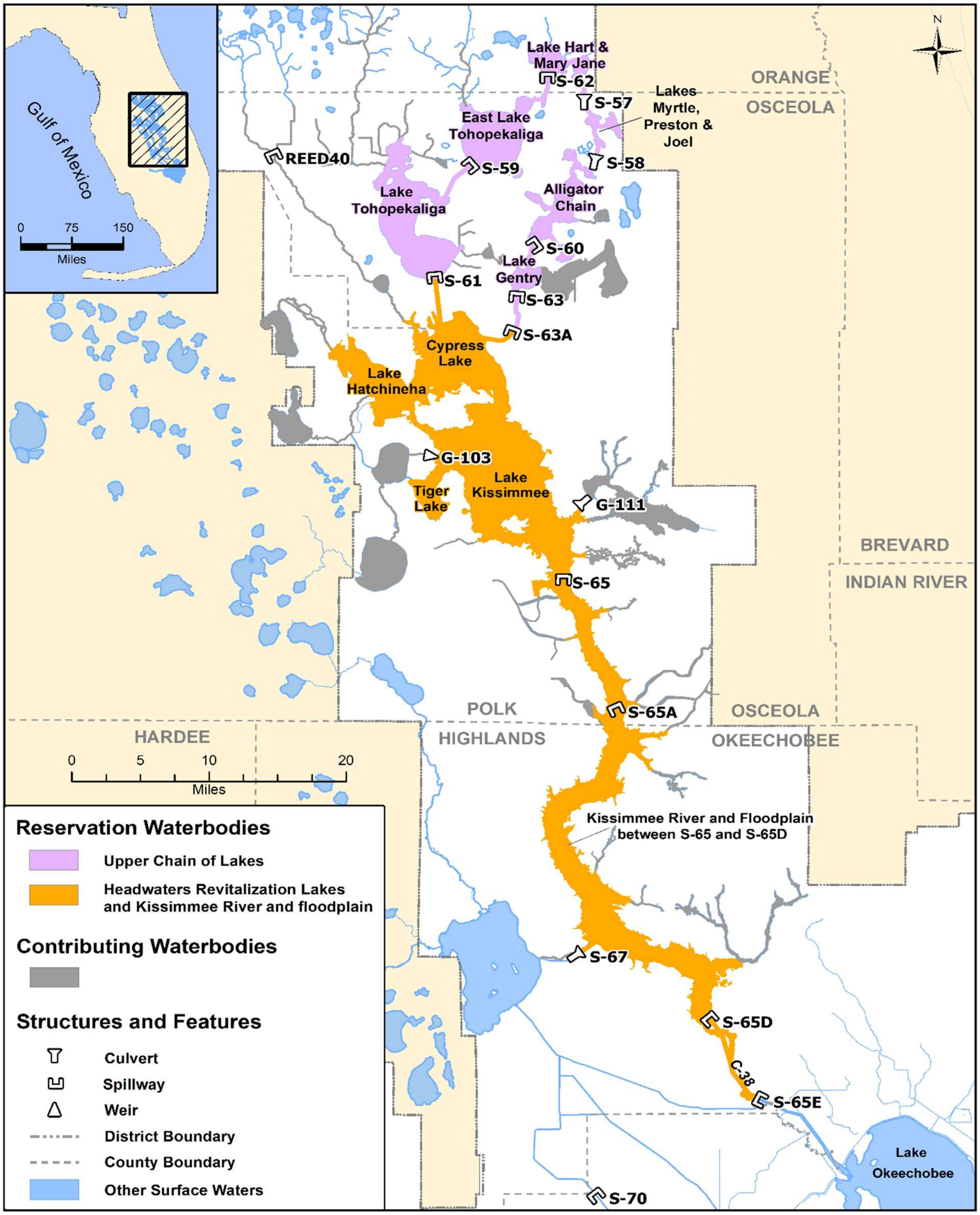


Figure A-1. Kissimmee River and Chain of Lakes reservation and contributing waterbodies.

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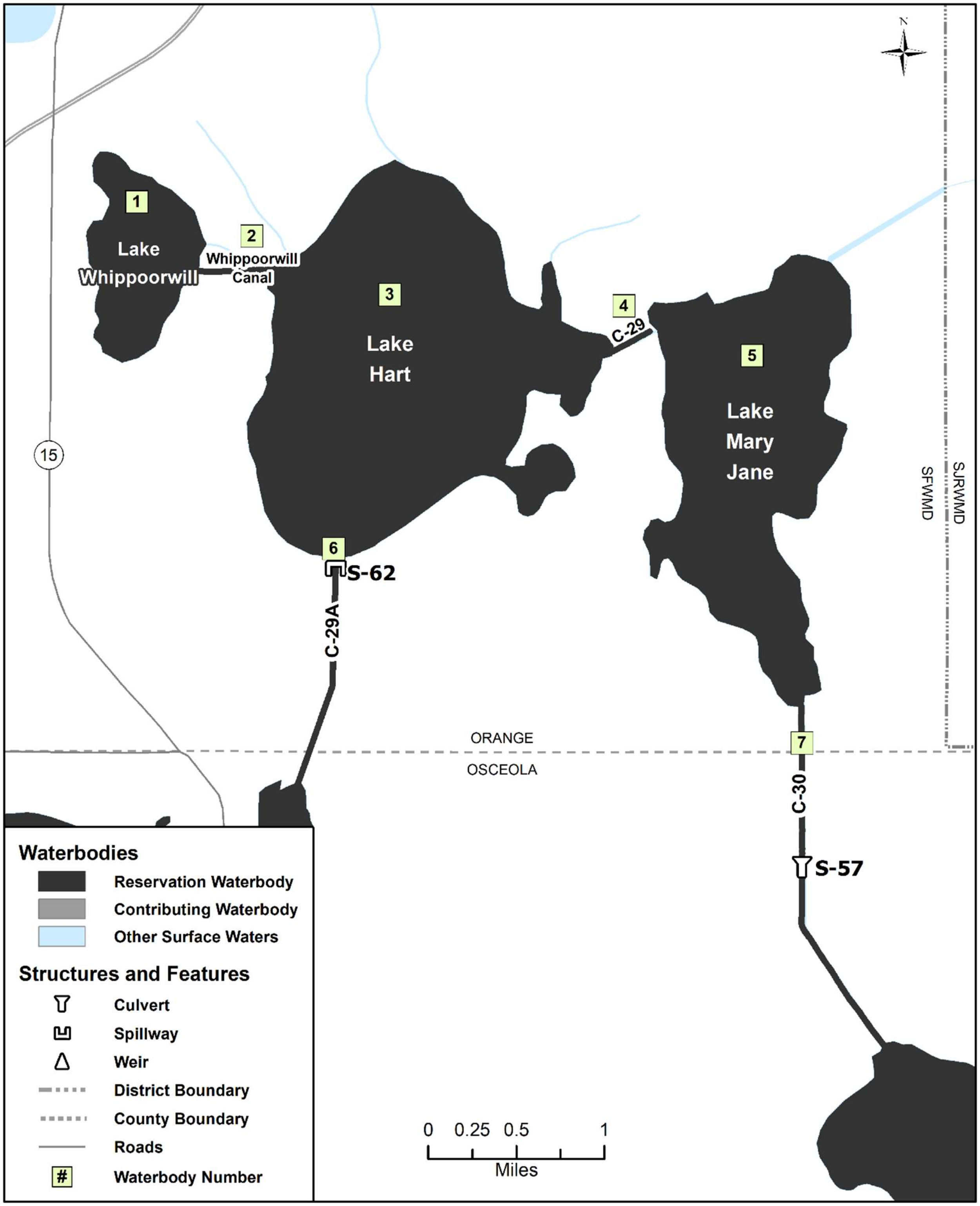

2428 Figure A-2. Lakes Hart-Mary Jane reservation waterbodies (no contributing waterbodies present).

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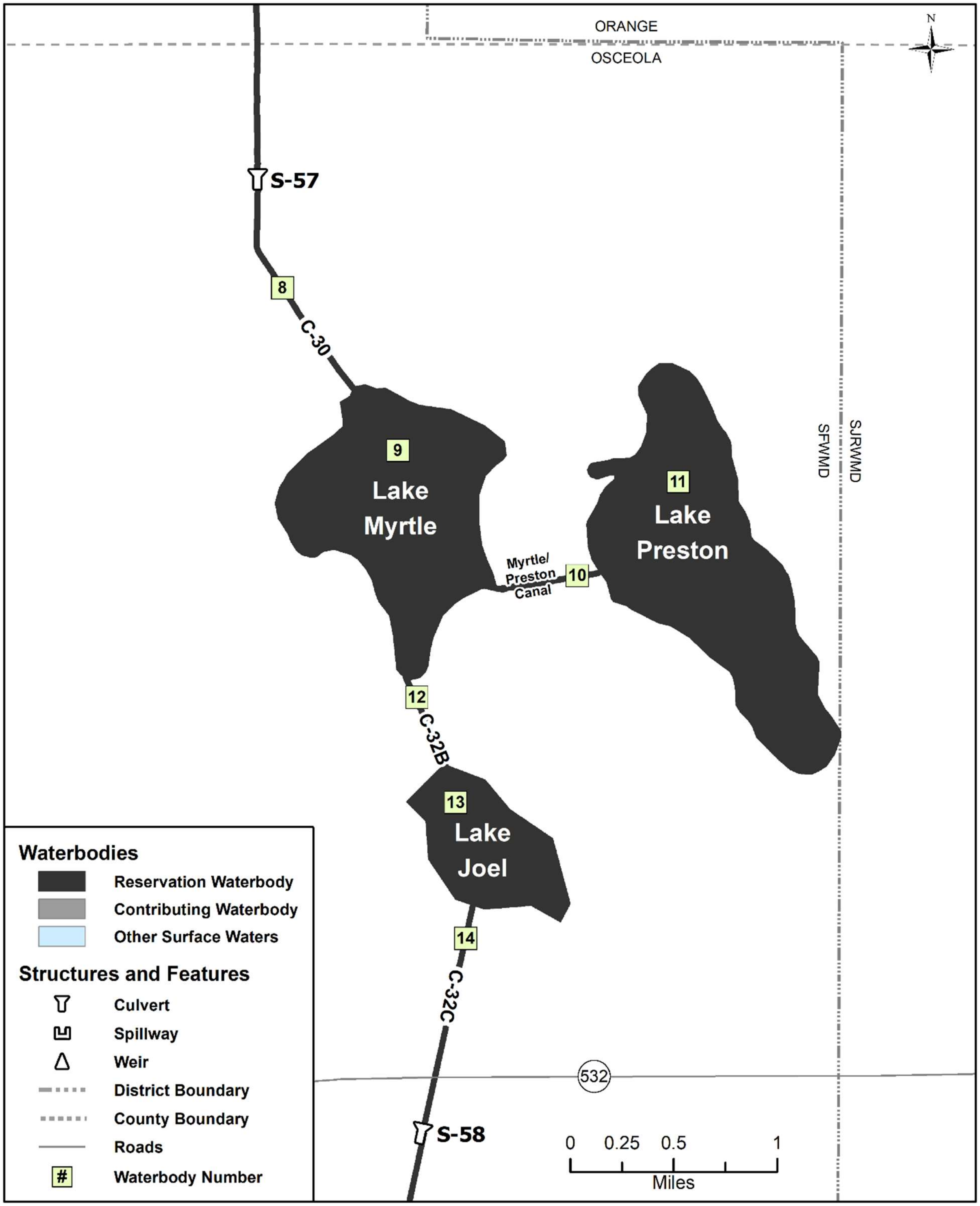
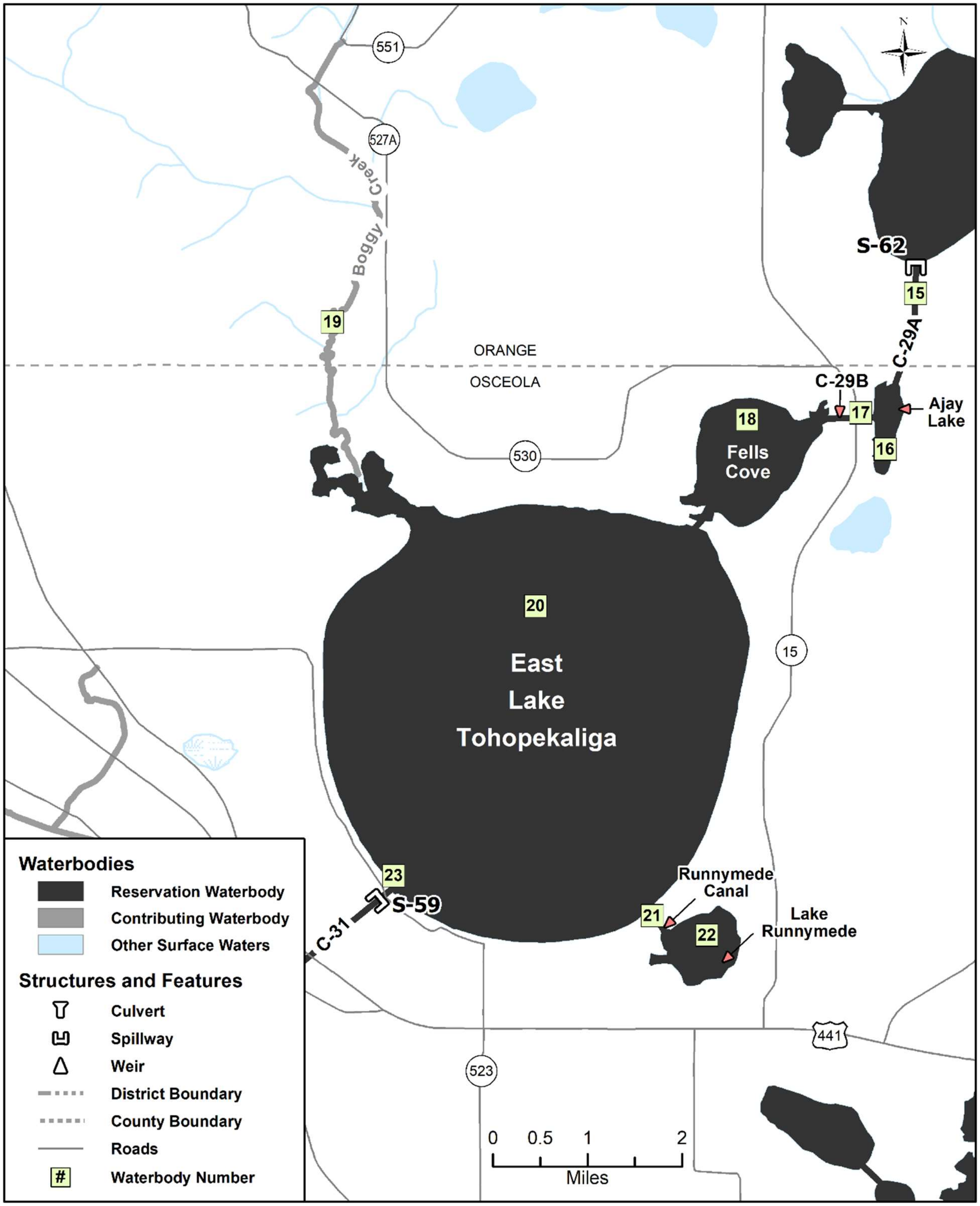


2430 Figure A-3. Lakes Myrtle-Preston-Joel reservation waterbodies (no contributing waterbodies present).



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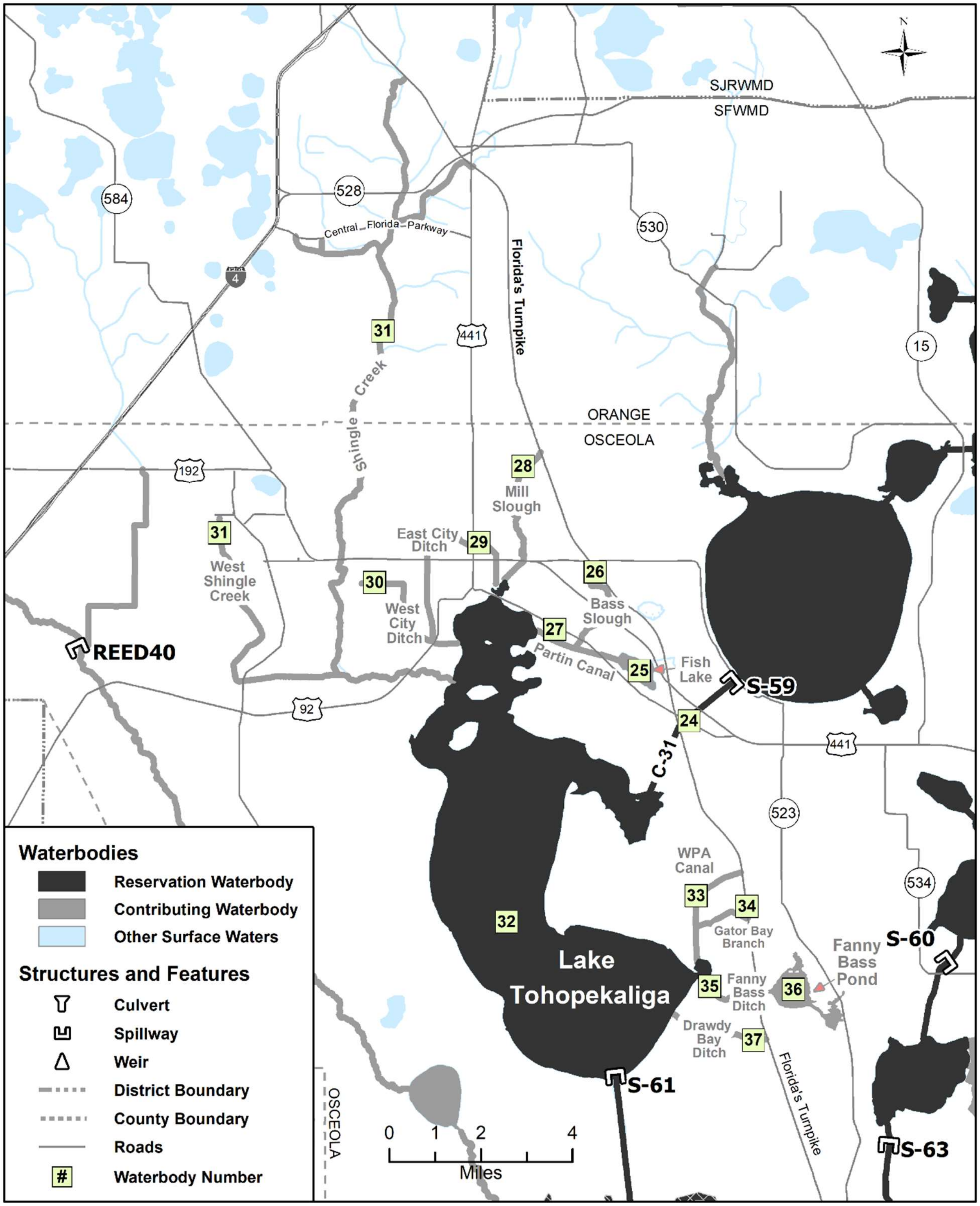
2432 Figure A-4. East Lake Tohopekaliga reservation and contributing waterbodies.



2434 Figure A-5. Lake Tohopekaliga reservation and contributing waterbodies.

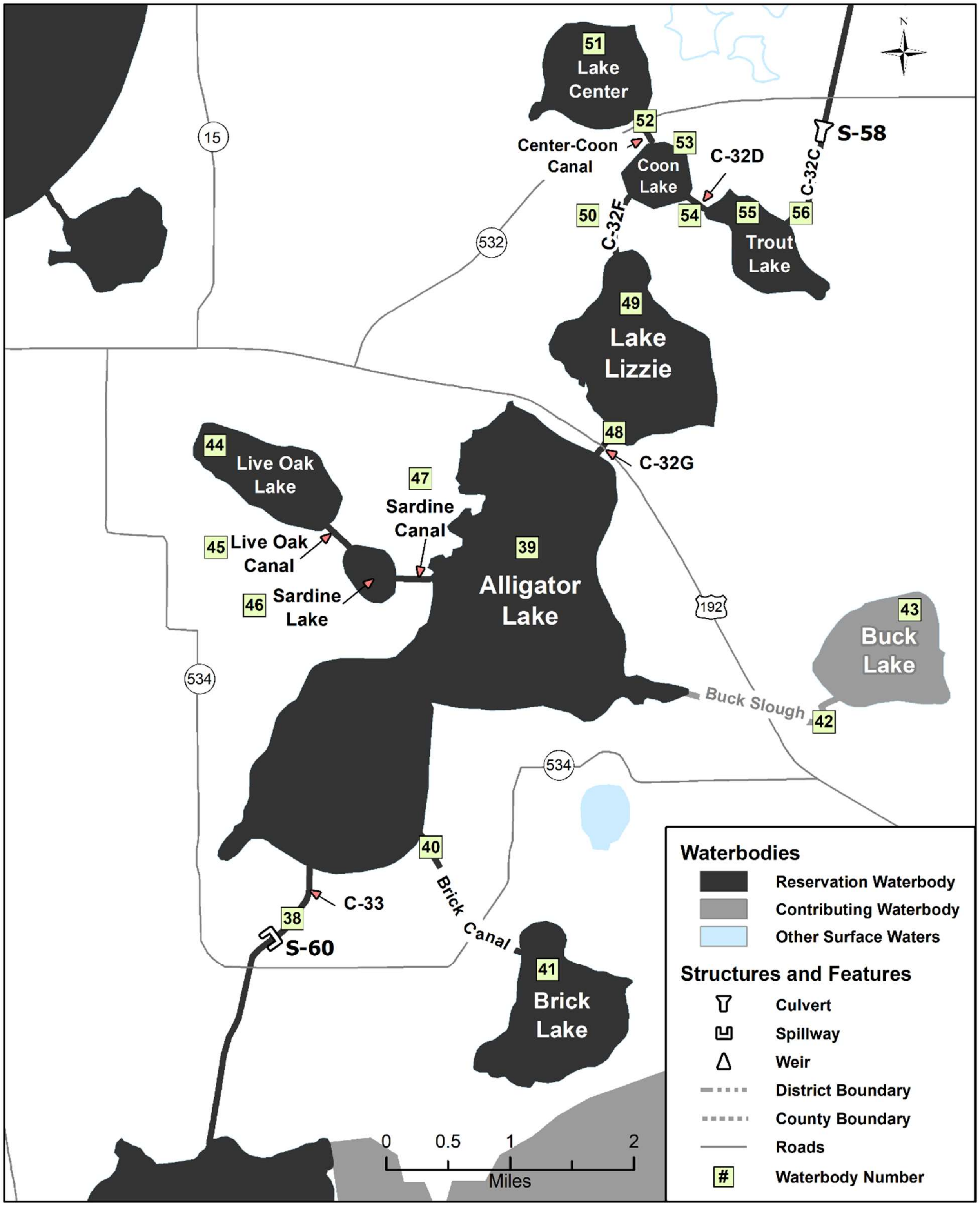


Figure A-6. Alligator Chain of Lakes reservation and contributing waterbodies.

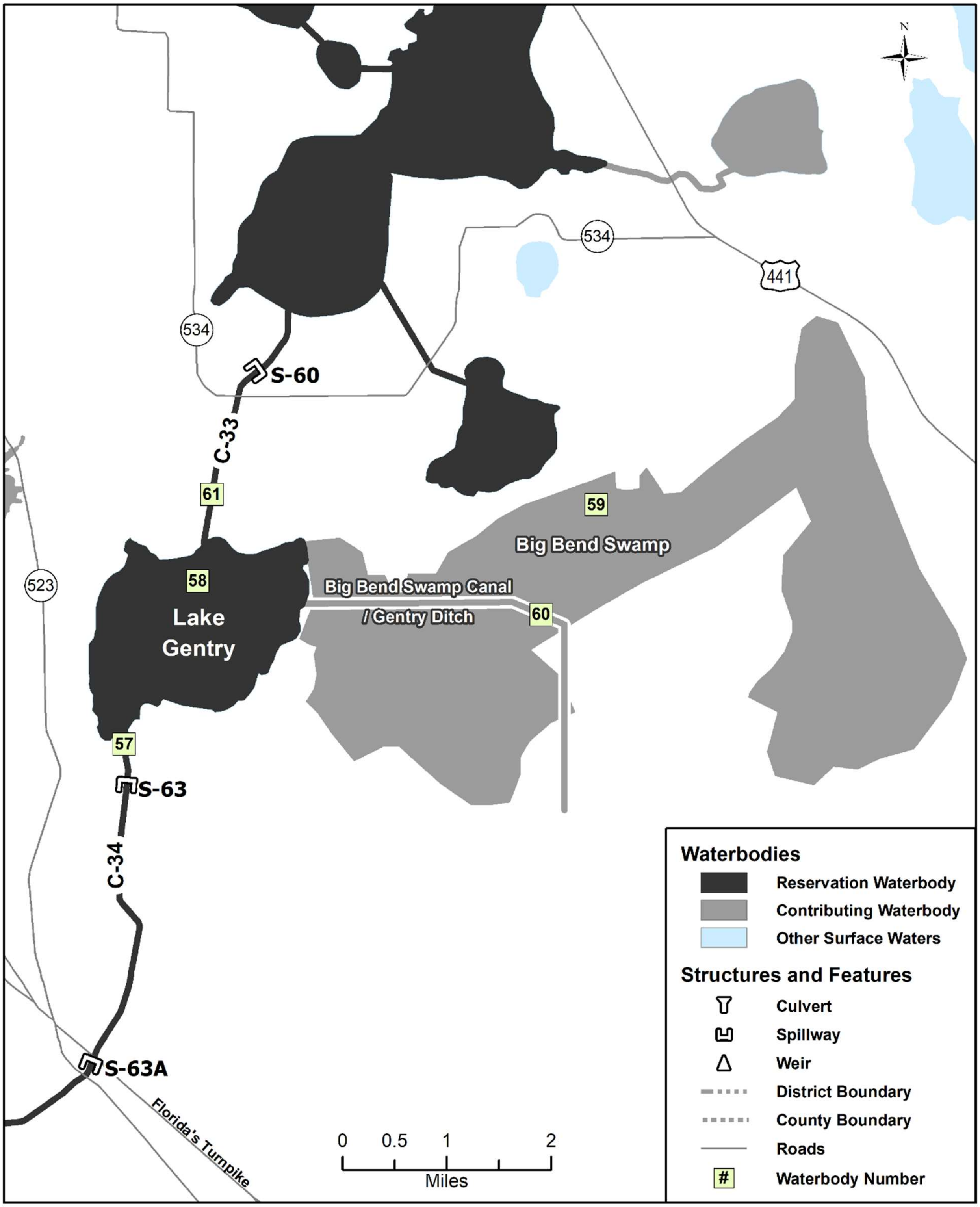


Figure A-7. Lake Gentry reservation and contributing waterbodies.

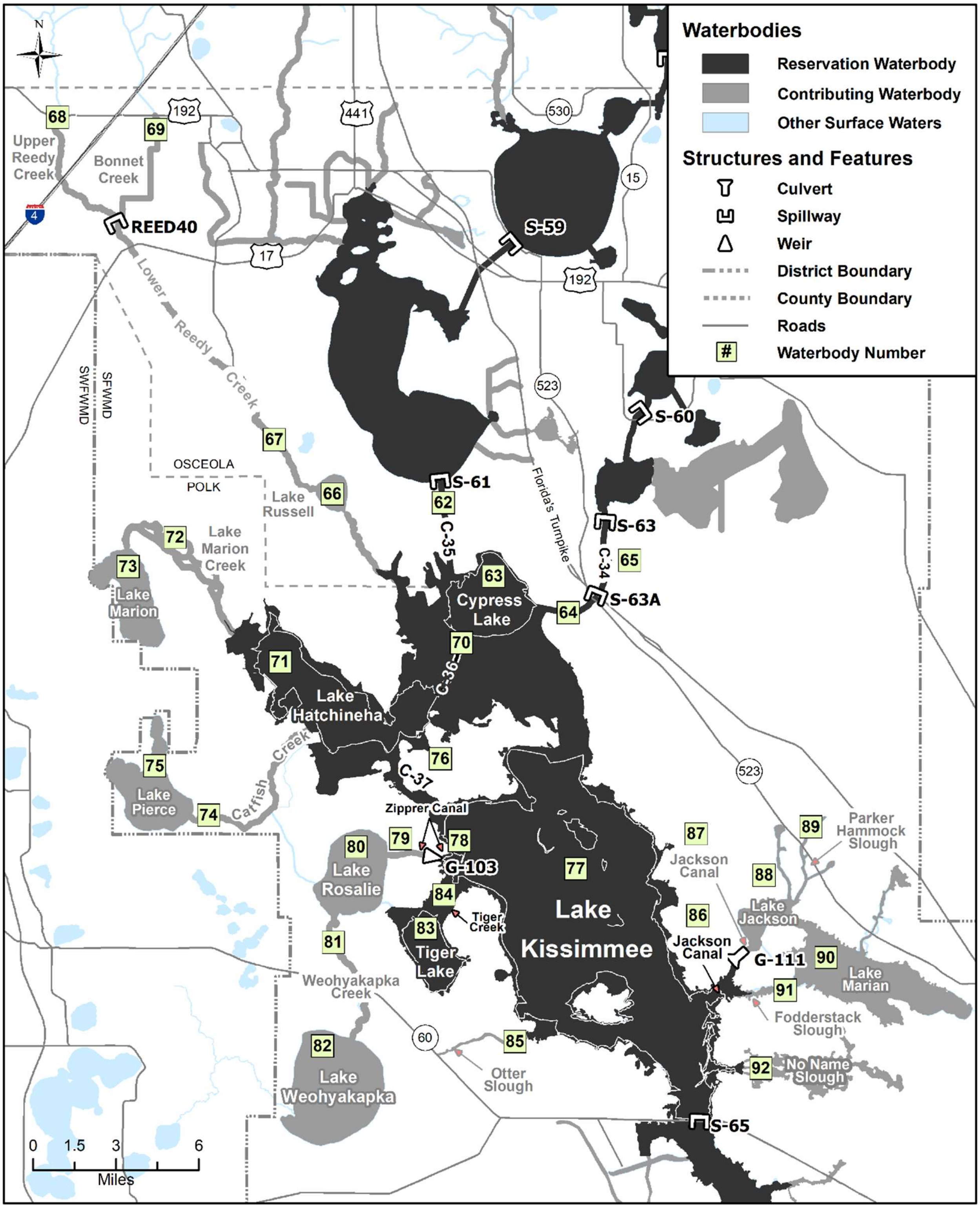


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Figure A-8. Headwaters Revitalization Lakes reservation and contributing waterbodies.

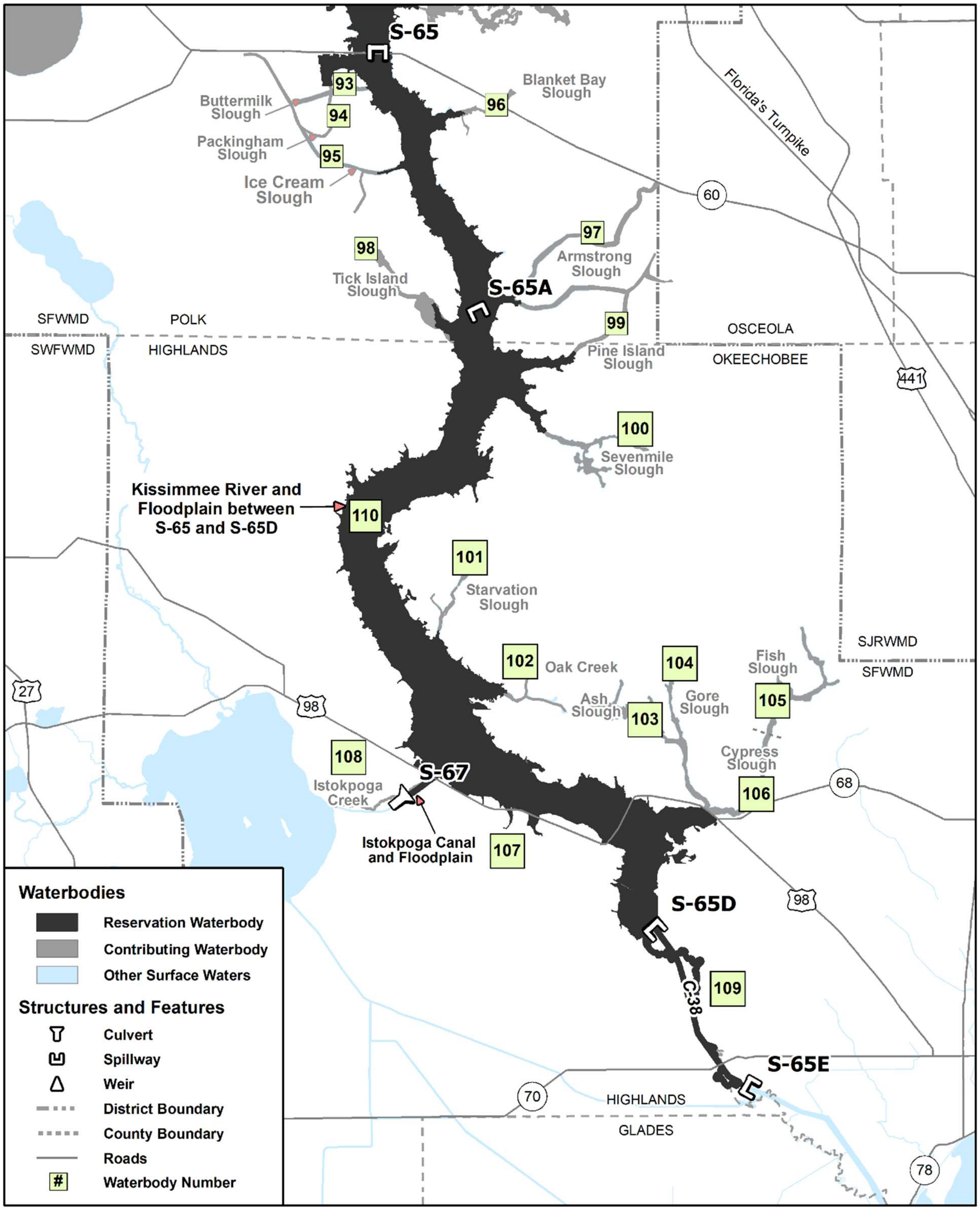


Figure A-9. Kissimmee River reservation and contributing waterbodies.

LITERATURE CITED

SFWMD. 2015. *Applicant's Handbook for Water Use Permit Applications within the South Florida Water Management District.* South Florida Water Management District, West Palm Beach, FL. September 7, 2015.

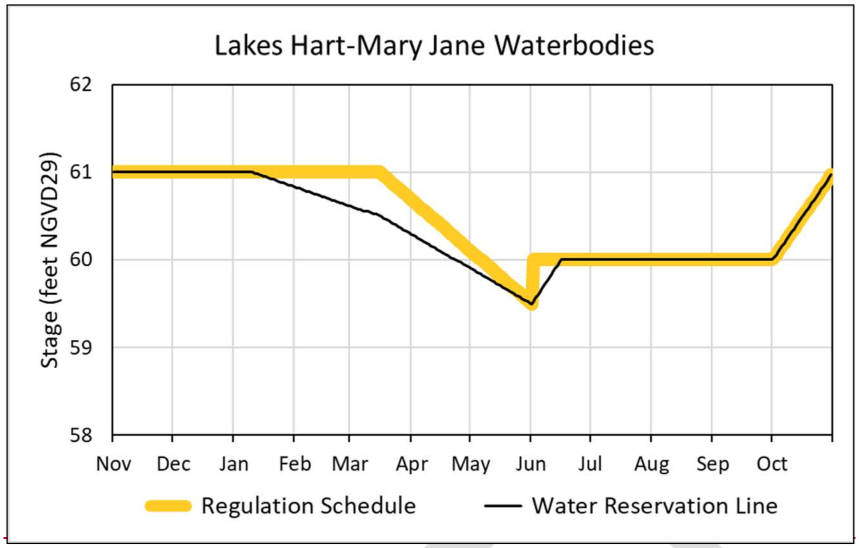
APPENDIX B: WATER PROPOSED FOR RESERVATION

All unallocated water in the Kissimmee River and in the Headwaters Revitalization Lakes up to the stages in the Headwaters Revitalization Schedule (HRS) at the S-65 water control structure will be reserved for the protection of fish and wildlife and to ensure the successful completion and implementation of the Kissimmee River Restoration Project (KRRP). For Upper Chain of Lakes (UCOL) reservation waterbodies, only water up to specific identified stages are proposed for reservation. These stages preserve the seasonal and interannual water level variability needed to support fish and wildlife in the UCOL reservation waterbodies. When daily lake stages are plotted over the course of a year (water reservation hydrograph), a water reservation line (WRL) emerges that demarcates the boundary between water needed (at or below the line) and water not needed (above the line) for the protection of fish and wildlife. **Figures B-1** to **B-7** provide the water reservation hydrographs with WRLs and current authorized regulation schedules for the reservation waterbodies. **Tables B-1** to **B-7** provide the daily water reservation stages plotted on the hydrographs for each reservation waterbody. The Water Reservation rules will reserve from allocation all water at or below the WRLs that is not allocated to existing legal users (permittees). Water above the WRLs will be available for future allocation, provided other regulatory permitting criteria are met.

The process to develop the WRLs for each UCOL reservation waterbody involved: 1) specifying a seasonal high stage and duration; 2) specifying a seasonal low stage; 3) connecting the seasonal high to the seasonal low stage with a straight-line recession event; 4) adjusting the resulting WRL to protect breeding season and wet season hydrological patterns (recession and ascension rates or breeding season water levels) that historically occurred; and 5) adjusting the resulting WRL to meet specific hydrologic requirements of fish and wildlife in the lake.

The seasonal high stage specified for the reservation waterbody defines an upper stage limit or threshold that preserves the maximum littoral extent in the waterbody, ensuring no reduction in wetland extent will occur below that elevation. For all UCOL reservation waterbodies, the seasonal high stage was specified 1) as the same high stage limit of the current stage regulation schedule, and 2) to occur on the first day the regulation schedule allows that stage to be reached (November 1).

Selection of the seasonal low stage establishes how much of the littoral zone can be dried out on an annual basis (i.e., it defines the boundary between permanently inundated aquatic vegetation and vegetation types that are seasonally inundated and require regular drying events). Under the current regulation schedules, lake stages are managed to reach the same low stage on May 31 every year, providing storage capacity for flood control at the beginning of the wet season. In order to protect the extent of permanently flooded marshes, the minimum stage for the UCOL reservation waterbodies was set as the minimum of the regulation schedule. This ensures the extent of annual drying events would not increase downslope from historical levels, which might lead to a reduction in overall open-water extent or an expansion of the littoral zone lakeward (downslope). A more detailed description of the approach used to establish the WRL for each UCOL reservation waterbody is provided in Chapter 5 of the main document.



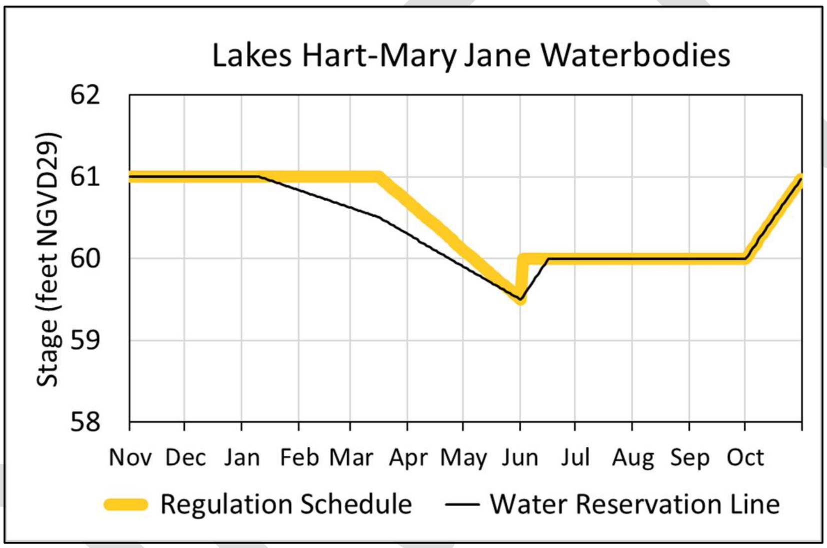
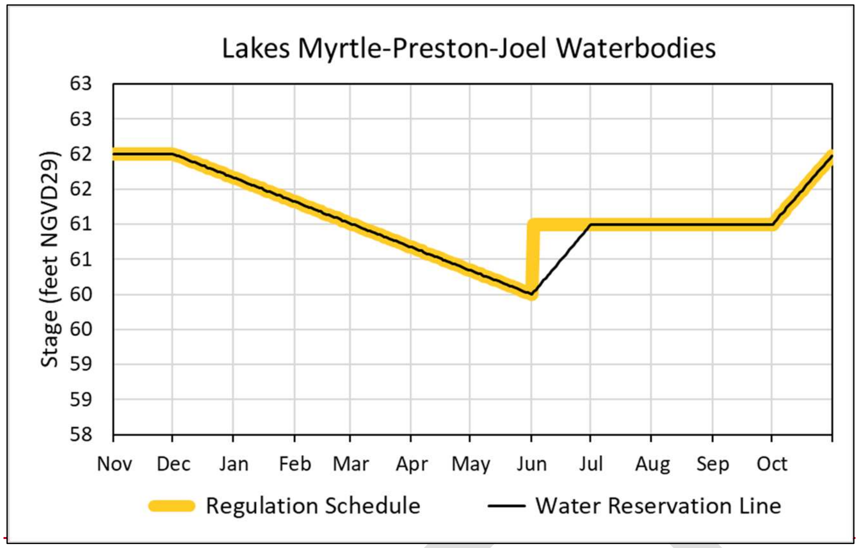


Figure B-1. Hydrograph of the current regulation schedule and the water reservation stage (water reservation line) for Lakes Hart-Mary Jane reservation waterbodies. All water up to the water reservation line is reserved from allocation for protection of fish and wildlife (derived from data in **Table B-1**).

Table B-1. Maximum daily water reservation stages for Lakes Hart-Mary Jane reservation waterbodies (black line in **Figure B-1**).

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	61.00	60.83	60.62	60.29	59.90	59.50	60.00	60.00	60.00	60.00	61.00	61.00
2	61.00	60.82	60.61	60.28	59.89	59.53	60.00	60.00	60.00	60.03	61.00	61.00
3	61.00	60.82	60.60	60.27	59.88	59.57	60.00	60.00	60.00	60.06	61.00	61.00
4	61.00	60.81	60.59	60.25	59.86	59.60	60.00	60.00	60.00	60.10	61.00	61.00
5	61.00	60.80	60.58	60.24	59.85	59.63	60.00	60.00	60.00	60.13	61.00	61.00
6	61.00	60.79	60.58	60.23	59.84	59.67	60.00	60.00	60.00	60.16	61.00	61.00
7	61.00	60.78	60.57	60.21	59.82	59.70	60.00	60.00	60.00	60.19	61.00	61.00
8	61.00	60.78	60.56	60.20	59.81	59.73	60.00	60.00	60.00	60.23	61.00	61.00
9	61.00	60.77	60.55	60.19	59.80	59.77	60.00	60.00	60.00	60.26	61.00	61.00
10	61.00	60.76	60.55	60.18	59.79	59.80	60.00	60.00	60.00	60.29	61.00	61.00
11	60.99	60.75	60.54	60.16	59.77	59.83	60.00	60.00	60.00	60.32	61.00	61.00
12	60.98	60.75	60.53	60.15	59.76	59.87	60.00	60.00	60.00	60.35	61.00	61.00

Day	January	February	March	April	May	June	July	August	September	October	November	December
13	60.98	60.74	60.52	60.14	59.75	59.90	60.00	60.00	60.00	60.39	61.00	61.00
14	60.97	60.73	60.52	60.12	59.73	59.93	60.00	60.00	60.00	60.42	61.00	61.00
15	60.96	60.72	60.51	60.11	59.72	59.97	60.00	60.00	60.00	60.45	61.00	61.00
16	60.95	60.72	60.50	60.10	59.71	60.00	60.00	60.00	60.00	60.48	61.00	61.00
17	60.95	60.71	60.49	60.08	59.69	60.00	60.00	60.00	60.00	60.52	61.00	61.00
18	60.94	60.70	60.47	60.07	59.68	60.00	60.00	60.00	60.00	60.55	61.00	61.00
19	60.93	60.69	60.46	60.06	59.67	60.00	60.00	60.00	60.00	60.58	61.00	61.00
20	60.92	60.68	60.45	60.05	59.66	60.00	60.00	60.00	60.00	60.61	61.00	61.00
21	60.92	60.68	60.44	60.03	59.64	60.00	60.00	60.00	60.00	60.65	61.00	61.00
22	60.91	60.67	60.42	60.02	59.63	60.00	60.00	60.00	60.00	60.68	61.00	61.00
23	60.90	60.66	60.41	60.01	59.62	60.00	60.00	60.00	60.00	60.71	61.00	61.00
24	60.89	60.65	60.40	59.99	59.60	60.00	60.00	60.00	60.00	60.74	61.00	61.00
25	60.88	60.65	60.38	59.98	59.59	60.00	60.00	60.00	60.00	60.77	61.00	61.00
26	60.88	60.64	60.37	59.97	59.58	60.00	60.00	60.00	60.00	60.81	61.00	61.00
27	60.87	60.63	60.36	59.95	59.56	60.00	60.00	60.00	60.00	60.84	61.00	61.00
28	60.86	60.62	60.34	59.94	59.55	60.00	60.00	60.00	60.00	60.87	61.00	61.00
29	60.85		60.33	59.93	59.54	60.00	60.00	60.00	60.00	60.90	61.00	61.00
30	60.85		60.32	59.92	59.53	60.00	60.00	60.00	60.00	60.94	61.00	61.00
31	60.84		60.31		59.51		60.00	60.00		60.97		61.00



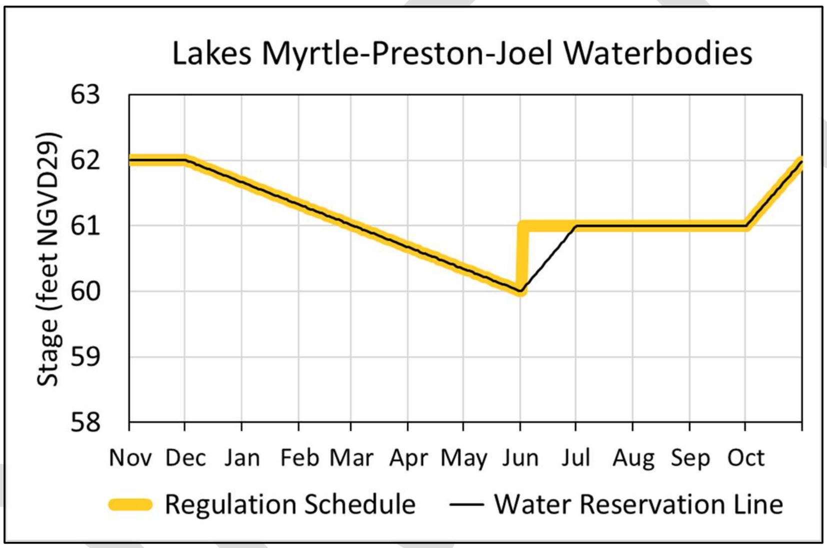
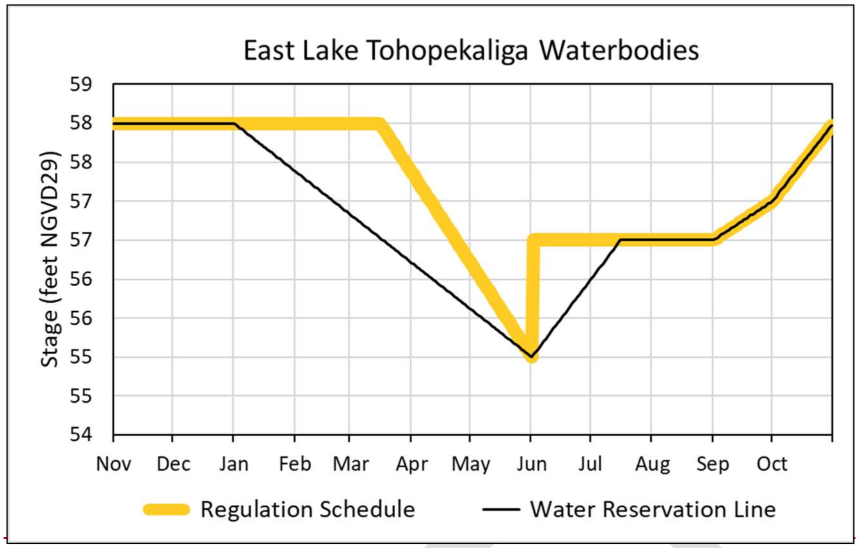


Figure B-2. Hydrograph of the current regulation schedule and the water reservation stage (water reservation line) for Lakes Myrtle-Preston-Joel reservation waterbodies. All water up to the water reservation line is reserved from allocation for protection of fish and wildlife (derived from data in **Table B-2**).

Table B-2. Maximum daily water reservation stages for Lakes Myrtle-Preston-Joel reservation waterbodies (black line in **Figure B-2**).

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	61.66	61.32	61.01	60.67	60.34	60.00	61.00	61.00	61.00	61.00	62.00	62.00
2	61.65	61.31	61.00	60.66	60.33	60.03	61.00	61.00	61.00	61.03	62.00	61.99
3	61.64	61.30	60.99	60.65	60.32	60.07	61.00	61.00	61.00	61.06	62.00	61.98
4	61.63	61.29	60.98	60.64	60.31	60.10	61.00	61.00	61.00	61.10	62.00	61.97
5	61.62	61.27	60.97	60.63	60.30	60.13	61.00	61.00	61.00	61.13	62.00	61.96
6	61.60	61.26	60.96	60.62	60.29	60.17	61.00	61.00	61.00	61.16	62.00	61.95
7	61.59	61.25	60.94	60.60	60.27	60.20	61.00	61.00	61.00	61.19	62.00	61.93
8	61.58	61.24	60.93	60.59	60.26	60.23	61.00	61.00	61.00	61.23	62.00	61.92
9	61.57	61.23	60.92	60.58	60.25	60.27	61.00	61.00	61.00	61.26	62.00	61.91
10	61.56	61.22	60.91	60.57	60.24	60.30	61.00	61.00	61.00	61.29	62.00	61.90
11	61.55	61.21	60.90	60.56	60.23	60.33	61.00	61.00	61.00	61.32	62.00	61.89
12	61.54	61.20	60.89	60.55	60.22	60.37	61.00	61.00	61.00	61.35	62.00	61.88

Day	January	February	March	April	May	June	July	August	September	October	November	December
13	61.53	61.19	60.88	60.54	60.21	60.40	61.00	61.00	61.00	61.39	62.00	61.87
14	61.52	61.18	60.87	60.53	60.20	60.43	61.00	61.00	61.00	61.42	62.00	61.86
15	61.51	61.16	60.86	60.52	60.19	60.47	61.00	61.00	61.00	61.45	62.00	61.85
16	61.49	61.15	60.85	60.51	60.18	60.50	61.00	61.00	61.00	61.48	62.00	61.84
17	61.48	61.14	60.84	60.49	60.16	60.53	61.00	61.00	61.00	61.52	62.00	61.83
18	61.47	61.13	60.82	60.48	60.15	60.57	61.00	61.00	61.00	61.55	62.00	61.81
19	61.46	61.12	60.81	60.47	60.14	60.60	61.00	61.00	61.00	61.58	62.00	61.80
20	61.45	61.11	60.80	60.46	60.13	60.63	61.00	61.00	61.00	61.61	62.00	61.79
21	61.44	61.10	60.79	60.45	60.12	60.67	61.00	61.00	61.00	61.65	62.00	61.78
22	61.43	61.09	60.78	60.44	60.11	60.70	61.00	61.00	61.00	61.68	62.00	61.77
23	61.42	61.08	60.77	60.43	60.10	60.73	61.00	61.00	61.00	61.71	62.00	61.76
24	61.41	61.07	60.76	60.42	60.09	60.77	61.00	61.00	61.00	61.74	62.00	61.75
25	61.40	61.05	60.75	60.41	60.08	60.80	61.00	61.00	61.00	61.77	62.00	61.74
26	61.38	61.04	60.74	60.40	60.07	60.83	61.00	61.00	61.00	61.81	62.00	61.73
27	61.37	61.03	60.73	60.38	60.05	60.87	61.00	61.00	61.00	61.84	62.00	61.72
28	61.36	61.02	60.71	60.37	60.04	60.90	61.00	61.00	61.00	61.87	62.00	61.70
29	61.35		60.70	60.36	60.03	60.93	61.00	61.00	61.00	61.90	62.00	61.69
30	61.34		60.69	60.35	60.02	60.97	61.00	61.00	61.00	61.94	62.00	61.68
31	61.33		60.68		60.01		61.00	61.00		61.97		61.67



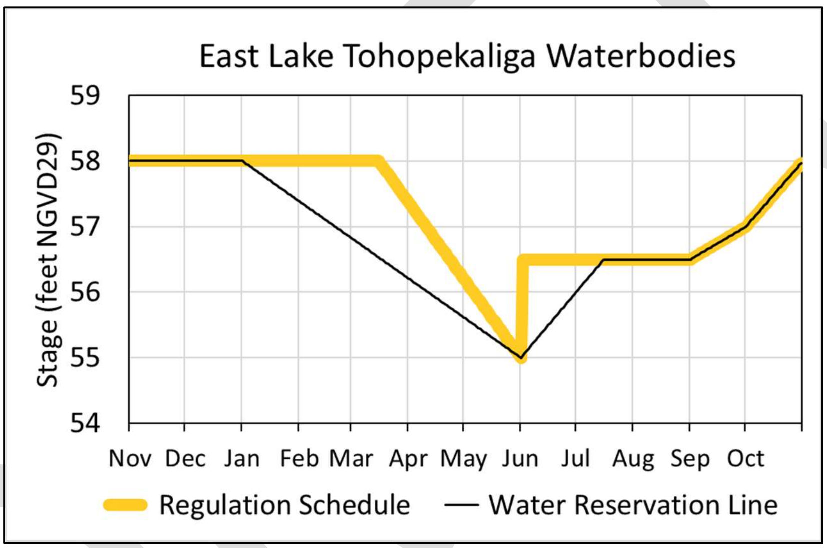
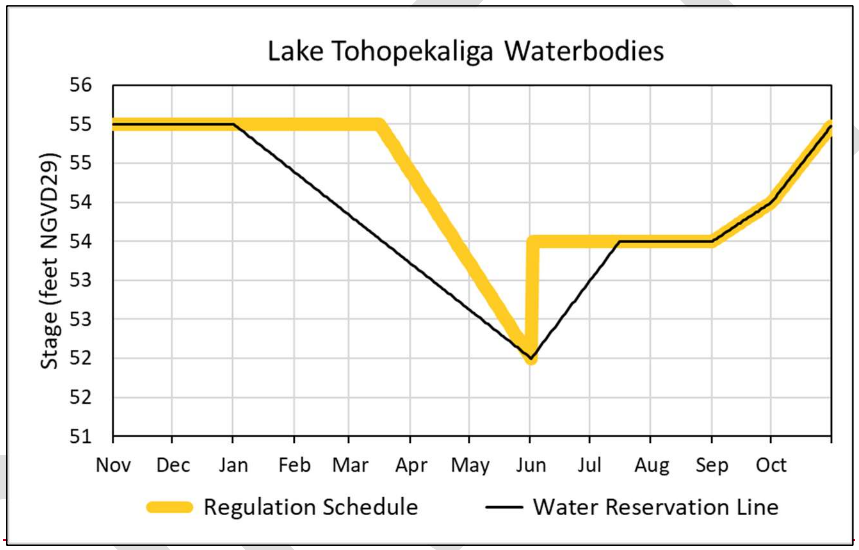


Figure B-3. Hydrograph of the current regulation schedule and the water reservation stage (water reservation line) for East Lake Tohopekaliga reservation waterbodies. All water up to the water reservation line is reserved from allocation for protection of fish and wildlife (derived from data in **Table B-3**).

Table B-3. Maximum daily water reservation stages for East Lake Tohopekaliga reservation waterbodies (black line in **Figure B-3**).

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	58.00	57.38	56.83	56.21	55.62	55.00	56.00	56.50	56.50	57.00	58.00	58.00
2	57.98	57.36	56.81	56.19	55.60	55.03	56.03	56.50	56.52	57.03	58.00	58.00
3	57.96	57.34	56.79	56.17	55.58	55.07	56.07	56.50	56.53	57.06	58.00	58.00
4	57.94	57.32	56.77	56.15	55.56	55.10	56.10	56.50	56.55	57.10	58.00	58.00
5	57.92	57.30	56.75	56.13	55.54	55.13	56.13	56.50	56.57	57.13	58.00	58.00
6	57.90	57.28	56.73	56.11	55.52	55.17	56.17	56.50	56.58	57.16	58.00	58.00
7	57.88	57.26	56.71	56.09	55.50	55.20	56.20	56.50	56.60	57.19	58.00	58.00
8	57.86	57.25	56.69	56.07	55.48	55.23	56.23	56.50	56.62	57.23	58.00	58.00
9	57.84	57.23	56.67	56.05	55.46	55.27	56.27	56.50	56.63	57.26	58.00	58.00
10	57.82	57.21	56.65	56.03	55.44	55.30	56.30	56.50	56.65	57.29	58.00	58.00
11	57.80	57.19	56.63	56.01	55.42	55.33	56.33	56.50	56.67	57.32	58.00	58.00
12	57.78	57.17	56.61	55.99	55.40	55.37	56.37	56.50	56.68	57.35	58.00	58.00

13	57.76	57.15	56.59	55.97	55.38	55.40	56.40	56.50	56.70	57.39	58.00	58.00
14	57.74	57.13	56.57	55.95	55.36	55.43	56.43	56.50	56.72	57.42	58.00	58.00
15	57.72	57.11	56.55	55.93	55.34	55.47	56.47	56.50	56.73	57.45	58.00	58.00
16	57.70	57.09	56.53	55.91	55.32	55.50	56.50	56.50	56.75	57.48	58.00	58.00
17	57.68	57.07	56.51	55.89	55.30	55.53	56.50	56.50	56.77	57.52	58.00	58.00
18	57.66	57.05	56.49	55.87	55.28	55.57	56.50	56.50	56.78	57.55	58.00	58.00
19	57.64	57.03	56.47	55.85	55.26	55.60	56.50	56.50	56.80	57.58	58.00	58.00
20	57.62	57.01	56.45	55.83	55.24	55.63	56.50	56.50	56.82	57.61	58.00	58.00
21	57.60	56.99	56.43	55.81	55.22	55.67	56.50	56.50	56.83	57.65	58.00	58.00
22	57.58	56.97	56.41	55.79	55.20	55.70	56.50	56.50	56.85	57.68	58.00	58.00
23	57.56	56.95	56.39	55.77	55.18	55.73	56.50	56.50	56.87	57.71	58.00	58.00
24	57.54	56.93	56.37	55.75	55.16	55.77	56.50	56.50	56.88	57.74	58.00	58.00
25	57.52	56.91	56.35	55.74	55.14	55.80	56.50	56.50	56.90	57.77	58.00	58.00
26	57.50	56.89	56.33	55.72	55.12	55.83	56.50	56.50	56.92	57.81	58.00	58.00
27	57.48	56.87	56.31	55.70	55.10	55.87	56.50	56.50	56.93	57.84	58.00	58.00
28	57.46	56.85	56.29	55.68	55.08	55.90	56.50	56.50	56.95	57.87	58.00	58.00
29	57.44		56.27	55.66	55.06	55.93	56.50	56.50	56.97	57.90	58.00	58.00
30	57.42		56.25	55.64	55.04	55.97	56.50	56.50	56.98	57.94	58.00	58.00
31	57.40		56.23		55.02		56.50	56.50		57.97		58.00



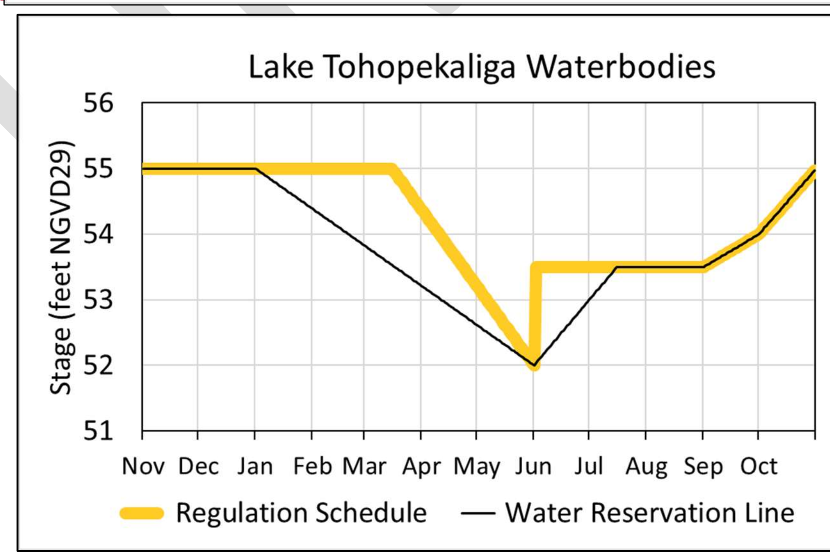
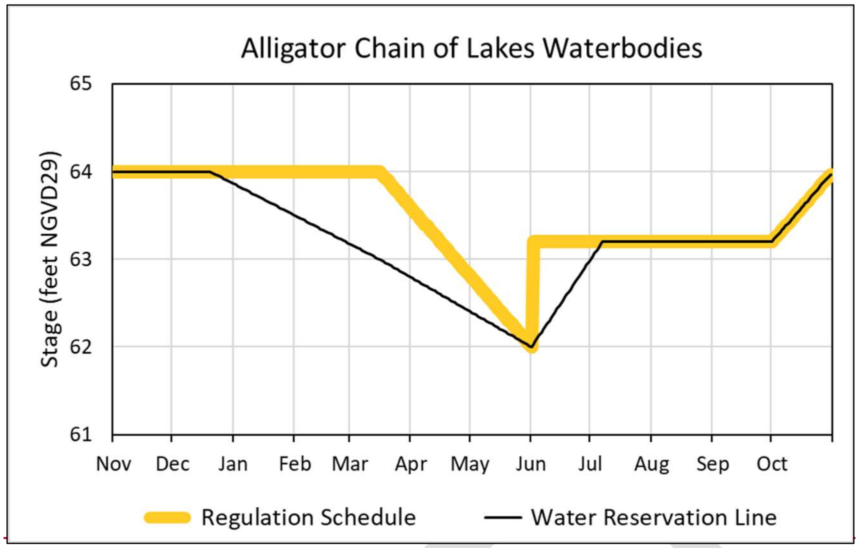


Figure B-4. Hydrograph of the current regulation schedule and the water reservation stage (water reservation line) for Lake Tohopekaliga reservation waterbodies. All water up to the water reservation line is reserved from allocation for protection of fish and wildlife (derived from data in **Table B-4**).

Table B-4. Maximum daily water reservation stages for Lake Tohopekaliga reservation waterbodies (black line in **Figure B-4**).

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	55.00	54.38	53.83	53.21	52.62	52.00	53.00	53.50	53.50	54.00	55.00	55.00
2	54.98	54.36	53.81	53.19	52.60	52.03	53.03	53.50	53.52	54.03	55.00	55.00
3	54.96	54.34	53.79	53.17	52.58	52.07	53.07	53.50	53.53	54.06	55.00	55.00
4	54.94	54.32	53.77	53.15	52.56	52.10	53.10	53.50	53.55	54.10	55.00	55.00
5	54.92	54.30	53.75	53.13	52.54	52.13	53.13	53.50	53.57	54.13	55.00	55.00
6	54.90	54.28	53.73	53.11	52.52	52.17	53.17	53.50	53.58	54.16	55.00	55.00
7	54.88	54.26	53.71	53.09	52.50	52.20	53.20	53.50	53.60	54.19	55.00	55.00
8	54.86	54.25	53.69	53.07	52.48	52.23	53.23	53.50	53.62	54.23	55.00	55.00
9	54.84	54.23	53.67	53.05	52.46	52.27	53.27	53.50	53.63	54.26	55.00	55.00
10	54.82	54.21	53.65	53.03	52.44	52.30	53.30	53.50	53.65	54.29	55.00	55.00
11	54.80	54.19	53.63	53.01	52.42	52.33	53.33	53.50	53.67	54.32	55.00	55.00
12	54.78	54.17	53.61	52.99	52.40	52.37	53.37	53.50	53.68	54.35	55.00	55.00
13	54.76	54.15	53.59	52.97	52.38	52.40	53.40	53.50	53.70	54.39	55.00	55.00
14	54.74	54.13	53.57	52.95	52.36	52.43	53.43	53.50	53.72	54.42	55.00	55.00
15	54.72	54.11	53.55	52.93	52.34	52.47	53.47	53.50	53.73	54.45	55.00	55.00
16	54.70	54.09	53.53	52.91	52.32	52.50	53.50	53.50	53.75	54.48	55.00	55.00
17	54.68	54.07	53.51	52.89	52.30	52.53	53.50	53.50	53.77	54.52	55.00	55.00
18	54.66	54.05	53.49	52.87	52.28	52.57	53.50	53.50	53.78	54.55	55.00	55.00
19	54.64	54.03	53.47	52.85	52.26	52.60	53.50	53.50	53.80	54.58	55.00	55.00
20	54.62	54.01	53.45	52.83	52.24	52.63	53.50	53.50	53.82	54.61	55.00	55.00
21	54.60	53.99	53.43	52.81	52.22	52.67	53.50	53.50	53.83	54.65	55.00	55.00
22	54.58	53.97	53.41	52.79	52.20	52.70	53.50	53.50	53.85	54.68	55.00	55.00
23	54.56	53.95	53.39	52.77	52.18	52.73	53.50	53.50	53.87	54.71	55.00	55.00
24	54.54	53.93	53.37	52.75	52.16	52.77	53.50	53.50	53.88	54.74	55.00	55.00
25	54.52	53.91	53.35	52.74	52.14	52.80	53.50	53.50	53.90	54.77	55.00	55.00
26	54.50	53.89	53.33	52.72	52.12	52.83	53.50	53.50	53.92	54.81	55.00	55.00
27	54.48	53.87	53.31	52.70	52.10	52.87	53.50	53.50	53.93	54.84	55.00	55.00
28	54.46	53.85	53.29	52.68	52.08	52.90	53.50	53.50	53.95	54.87	55.00	55.00
29	54.44		53.27	52.66	52.06	52.93	53.50	53.50	53.97	54.90	55.00	55.00
30	54.42		53.25	52.64	52.04	52.97	53.50	53.50	53.98	54.94	55.00	55.00
31	54.40		53.23		52.02		53.50	53.50		54.97		55.00



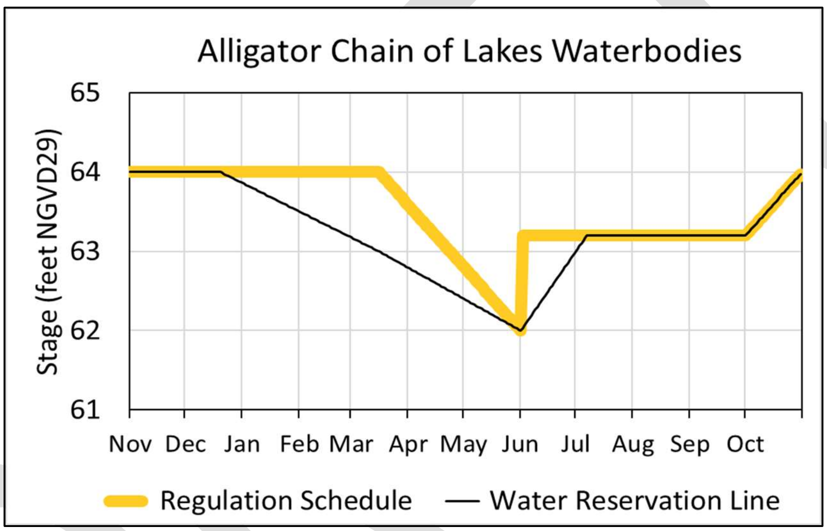
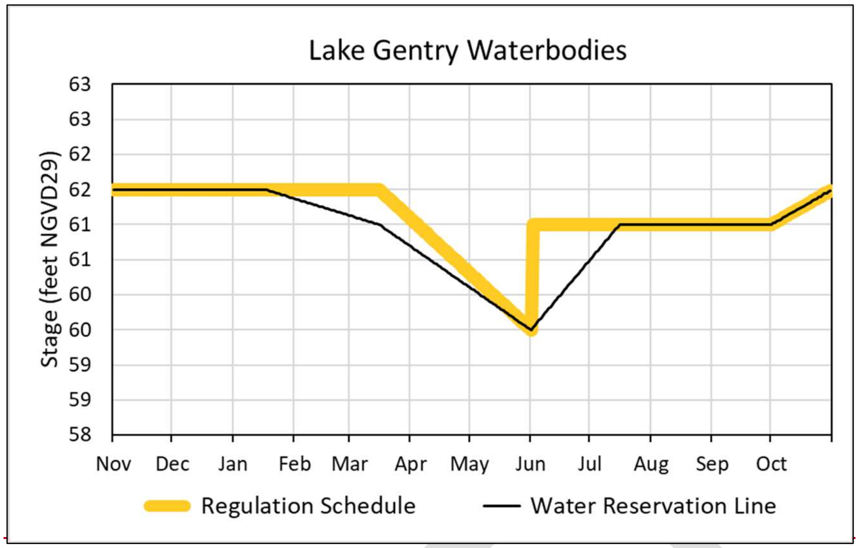


Figure B-5. Hydrograph of the current regulation schedule and the water reservation stage (water reservation line) for Alligator Chain of Lakes reservation waterbodies. All water up to the water reservation line is reserved from allocation for protection of fish and wildlife (derived from data in **Table B-5**).

Table B-5. Maximum daily water reservation stages for Alligator Chain of Lakes reservation waterbodies (black line in **Figure B-5**).

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	63.86	63.50	63.17	62.79	62.40	62.00	63.00	63.20	63.20	63.20	64.00	64.00
2	63.85	63.49	63.16	62.78	62.39	62.03	63.03	63.20	63.20	63.23	64.00	64.00
3	63.84	63.48	63.15	62.77	62.38	62.07	63.07	63.20	63.20	63.25	64.00	64.00
4	63.83	63.47	63.14	62.75	62.36	62.10	63.10	63.20	63.20	63.28	64.00	64.00
5	63.81	63.45	63.13	62.74	62.35	62.13	63.13	63.20	63.20	63.30	64.00	64.00
6	63.80	63.44	63.12	62.73	62.34	62.17	63.17	63.20	63.20	63.33	64.00	64.00
7	63.79	63.43	63.10	62.71	62.32	62.20	63.20	63.20	63.20	63.35	64.00	64.00
8	63.78	63.42	63.09	62.70	62.31	62.23	63.20	63.20	63.20	63.38	64.00	64.00
9	63.77	63.41	63.08	62.69	62.30	62.27	63.20	63.20	63.20	63.41	64.00	64.00
10	63.76	63.40	63.07	62.68	62.29	62.30	63.20	63.20	63.20	63.43	64.00	64.00
11	63.74	63.38	63.06	62.66	62.27	62.33	63.20	63.20	63.20	63.46	64.00	64.00
12	63.73	63.37	63.05	62.65	62.26	62.37	63.20	63.20	63.20	63.48	64.00	64.00

Day	January	February	March	April	May	June	July	August	September	October	November	December
13	63.72	63.36	63.03	62.64	62.25	62.40	63.20	63.20	63.20	63.51	64.00	64.00
14	63.71	63.35	63.02	62.62	62.23	62.43	63.20	63.20	63.20	63.54	64.00	64.00
15	63.70	63.34	63.01	62.61	62.22	62.47	63.20	63.20	63.20	63.56	64.00	64.00
16	63.69	63.33	63.00	62.60	62.21	62.50	63.20	63.20	63.20	63.59	64.00	64.00
17	63.67	63.31	62.99	62.58	62.19	62.53	63.20	63.20	63.20	63.61	64.00	64.00
18	63.66	63.30	62.97	62.57	62.18	62.57	63.20	63.20	63.20	63.64	64.00	64.00
19	63.65	63.29	62.96	62.56	62.17	62.60	63.20	63.20	63.20	63.66	64.00	64.00
20	63.64	63.28	62.95	62.55	62.16	62.63	63.20	63.20	63.20	63.69	64.00	64.00
21	63.63	63.27	62.94	62.53	62.14	62.67	63.20	63.20	63.20	63.72	64.00	63.99
22	63.62	63.26	62.92	62.52	62.13	62.70	63.20	63.20	63.20	63.74	64.00	63.98
23	63.60	63.24	62.91	62.51	62.12	62.73	63.20	63.20	63.20	63.77	64.00	63.97
24	63.59	63.23	62.90	62.49	62.10	62.77	63.20	63.20	63.20	63.79	64.00	63.95
25	63.58	63.22	62.88	62.48	62.09	62.80	63.20	63.20	63.20	63.82	64.00	63.94
26	63.57	63.21	62.87	62.47	62.08	62.83	63.20	63.20	63.20	63.85	64.00	63.93
27	63.56	63.20	62.86	62.45	62.06	62.87	63.20	63.20	63.20	63.87	64.00	63.92
28	63.55	63.19	62.84	62.44	62.05	62.90	63.20	63.20	63.20	63.90	64.00	63.91
29	63.53		62.83	62.43	62.04	62.93	63.20	63.20	63.20	63.92	64.00	63.90
30	63.52		62.82	62.42	62.03	62.97	63.20	63.20	63.20	63.95	64.00	63.88
31	63.51		62.81		62.01		63.20	63.20		63.97		63.87



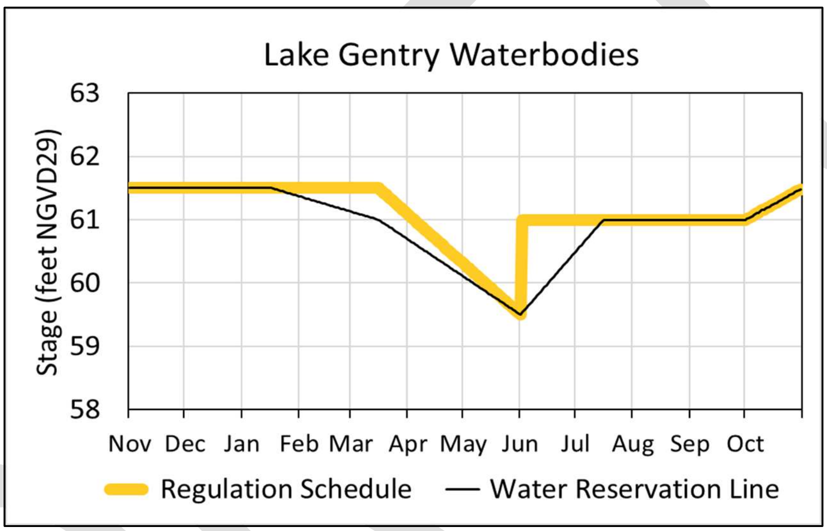
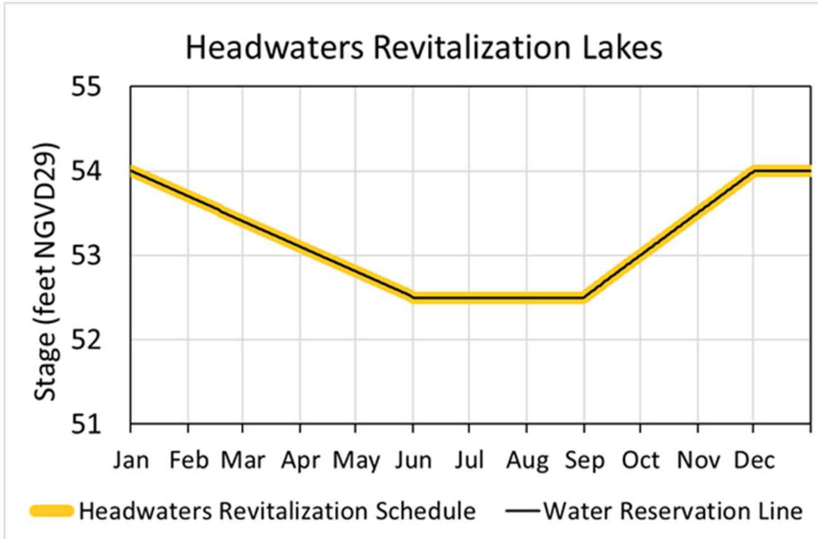


Figure B-6. Hydrograph of the current regulation schedule and the water reservation stage (water reservation line) for Lake Gentry reservation waterbodies. All water up to the water reservation line is reserved from allocation for protection of fish and wildlife (derived from data in **Table B-6**).

Table B-6. Maximum daily water reservation stages for Lake Gentry reservation waterbodies (black line in **Figure B-6**).

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	61.50	61.37	61.13	60.69	60.10	59.50	60.50	61.00	61.00	61.00	61.50	61.50
2	61.50	61.36	61.12	60.67	60.08	59.53	60.53	61.00	61.00	61.02	61.50	61.50
3	61.50	61.35	61.11	60.65	60.06	59.57	60.57	61.00	61.00	61.03	61.50	61.50
4	61.50	61.34	61.10	60.63	60.05	59.60	60.60	61.00	61.00	61.05	61.50	61.50
5	61.50	61.34	61.09	60.61	60.03	59.63	60.63	61.00	61.00	61.06	61.50	61.50
6	61.50	61.33	61.09	60.59	60.01	59.67	60.67	61.00	61.00	61.08	61.50	61.50
7	61.50	61.32	61.08	60.57	59.99	59.70	60.70	61.00	61.00	61.10	61.50	61.50
8	61.50	61.31	61.07	60.55	59.97	59.73	60.73	61.00	61.00	61.11	61.50	61.50
9	61.50	61.30	61.06	60.53	59.95	59.77	60.77	61.00	61.00	61.13	61.50	61.50
10	61.50	61.29	61.05	60.51	59.93	59.80	60.80	61.00	61.00	61.15	61.50	61.50
11	61.50	61.28	61.04	60.49	59.91	59.83	60.83	61.00	61.00	61.16	61.50	61.50
12	61.50	61.28	61.03	60.47	59.89	59.87	60.87	61.00	61.00	61.18	61.50	61.50

Day	January	February	March	April	May	June	July	August	September	October	November	December
13	61.50	61.27	61.03	60.45	59.87	59.90	60.90	61.00	61.00	61.19	61.50	61.50
14	61.50	61.26	61.02	60.44	59.85	59.93	60.93	61.00	61.00	61.21	61.50	61.50
15	61.50	61.25	61.01	60.42	59.83	59.97	60.97	61.00	61.00	61.23	61.50	61.50
16	61.50	61.24	61.00	60.40	59.81	60.00	61.00	61.00	61.00	61.24	61.50	61.50
17	61.50	61.23	60.98	60.38	59.79	60.03	61.00	61.00	61.00	61.26	61.50	61.50
18	61.49	61.22	60.96	60.36	59.77	60.07	61.00	61.00	61.00	61.27	61.50	61.50
19	61.48	61.22	60.94	60.34	59.75	60.10	61.00	61.00	61.00	61.29	61.50	61.50
20	61.47	61.21	60.92	60.32	59.73	60.13	61.00	61.00	61.00	61.31	61.50	61.50
21	61.47	61.20	60.90	60.30	59.71	60.17	61.00	61.00	61.00	61.32	61.50	61.50
22	61.46	61.19	60.88	60.28	59.69	60.20	61.00	61.00	61.00	61.34	61.50	61.50
23	61.45	61.18	60.86	60.26	59.68	60.23	61.00	61.00	61.00	61.35	61.50	61.50
24	61.44	61.17	60.84	60.24	59.66	60.27	61.00	61.00	61.00	61.37	61.50	61.50
25	61.43	61.16	60.82	60.22	59.64	60.30	61.00	61.00	61.00	61.39	61.50	61.50
26	61.42	61.16	60.81	60.20	59.62	60.33	61.00	61.00	61.00	61.40	61.50	61.50
27	61.41	61.15	60.79	60.18	59.60	60.37	61.00	61.00	61.00	61.42	61.50	61.50
28	61.41	61.14	60.77	60.16	59.58	60.40	61.00	61.00	61.00	61.44	61.50	61.50
29	61.40		60.75	60.14	59.56	60.43	61.00	61.00	61.00	61.45	61.50	61.50
30	61.39		60.73	60.12	59.54	60.47	61.00	61.00	61.00	61.47	61.50	61.50
31	61.38		60.71		59.52		61.00	61.00		61.48		61.50



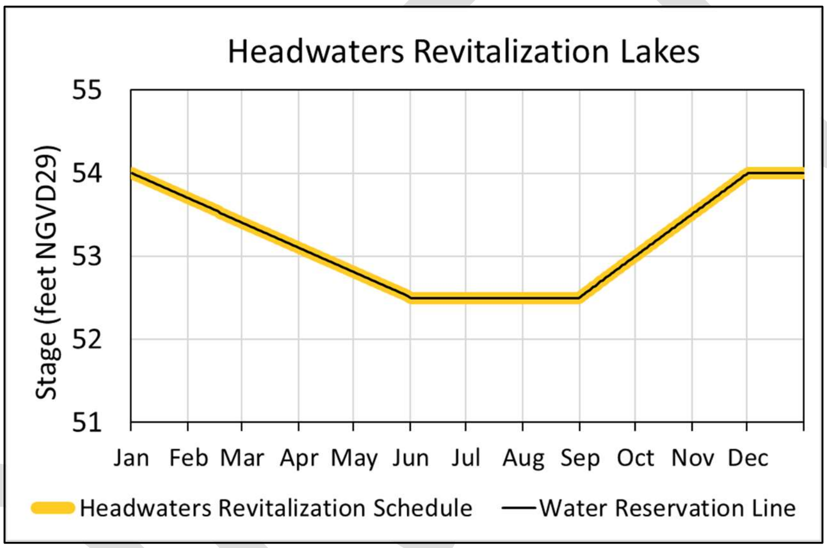


Figure B-7. Hydrograph of the authorized Headwaters Revitalization Schedule (HRS) at S-65 and the water reservation stage (water reservation line) for the Headwaters Revitalization Lakes reservation waterbodies. All water up to the water reservation line is reserved from allocation for protection of fish and wildlife (derived from data in **Table B-7**).

Table B-7. Maximum daily water reservation stages for the Headwaters Revitalization Lakes reservation waterbodies (black line in **Figure B-7**).

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	54.00	53.69	53.41	53.10	52.81	52.50	52.50	52.50	52.52	53.01	53.51	54.00
2	53.99	53.68	53.40	53.09	52.80	52.50	52.50	52.50	52.53	53.02	53.53	54.00
3	53.98	53.67	53.39	53.08	52.79	52.50	52.50	52.50	52.55	53.04	53.54	54.00
4	53.97	53.66	53.38	53.07	52.78	52.50	52.50	52.50	52.57	53.05	53.56	54.00
5	53.96	53.65	53.37	53.06	52.77	52.50	52.50	52.50	52.58	53.07	53.58	54.00
6	53.95	53.64	53.36	53.05	52.76	52.50	52.50	52.50	52.60	53.09	53.59	54.00
7	53.94	53.63	53.35	53.04	52.75	52.50	52.50	52.50	52.61	53.10	53.61	54.00
8	53.93	53.63	53.34	53.03	52.74	52.50	52.50	52.50	52.63	53.12	53.62	54.00
9	53.92	53.62	53.33	53.02	52.73	52.50	52.50	52.50	52.65	53.14	53.64	54.00
10	53.91	53.61	53.32	53.01	52.72	52.50	52.50	52.50	52.66	53.15	53.66	54.00
11	53.90	53.60	53.31	53.00	52.71	52.50	52.50	52.50	52.68	53.17	53.67	54.00
12	53.89	53.59	53.30	52.99	52.70	52.50	52.50	52.50	52.70	53.18	53.69	54.00

Day	January	February	March	April	May	June	July	August	September	October	November	December
13	53.88	53.58	53.29	52.98	52.69	52.50	52.50	52.50	52.71	53.20	53.71	54.00
14	53.87	53.57	53.28	52.97	52.68	52.50	52.50	52.50	52.73	53.22	53.72	54.00
15	53.86	53.56	53.27	52.96	52.67	52.50	52.50	52.50	52.74	53.23	53.74	54.00
16	53.85	53.55	53.26	52.95	52.66	52.50	52.50	52.50	52.76	53.25	53.76	54.00
17	53.84	53.54	53.25	52.94	52.65	52.50	52.50	52.50	52.78	53.27	53.77	54.00
18	53.83	53.53	53.24	52.93	52.64	52.50	52.50	52.50	52.79	53.28	53.79	54.00
19	53.82	53.52	53.23	52.92	52.63	52.50	52.50	52.50	52.81	53.30	53.80	54.00
20	53.81	53.51	53.22	52.91	52.62	52.50	52.50	52.50	52.83	53.32	53.82	54.00
21	53.80	53.50	53.21	52.90	52.61	52.50	52.50	52.50	52.84	53.33	53.84	54.00
22	53.79	53.49	53.20	52.89	52.60	52.50	52.50	52.50	52.86	53.35	53.85	54.00
23	53.78	53.48	53.19	52.88	52.59	52.50	52.50	52.50	52.88	53.36	53.87	54.00
24	53.77	53.47	53.18	52.88	52.58	52.50	52.50	52.50	52.89	53.38	53.89	54.00
25	53.76	53.46	53.17	52.87	52.57	52.50	52.50	52.50	52.91	53.40	53.90	54.00
26	53.75	53.45	53.16	52.86	52.56	52.50	52.50	52.50	52.92	53.41	53.92	54.00
27	53.74	53.44	53.15	52.85	52.55	52.50	52.50	52.50	52.94	53.43	53.93	54.00
28	53.73	53.43	53.14	52.84	52.54	52.50	52.50	52.50	52.96	53.45	53.95	54.00
29	53.72	53.42	53.13	52.83	52.53	52.50	52.50	52.50	52.97	53.46	53.97	54.00
30	53.71		53.12	52.82	52.52	52.50	52.50	52.50	52.99	53.48	53.98	54.00
31	53.70		53.11		52.51		52.50	52.50		53.49		54.00

APPENDIX C: DOCUMENTATION REPORT FOR THE UK-OPS MODEL

FINAL DRAFT

DOCUMENTATION REPORT FOR THE UPPER KISSIMMEE – OPERATIONS SIMULATION (UK-OPS) MODEL

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March 2020

ACKNOWLEDGMENTS

The Upper Kissimmee – Operations Simulation Model was developed at the request of Paul Linton, P.E., former Chief of the Water Management Office at the South Florida Water Management District (SFWMD). Mr. Linton had the initial idea to build an easy-to-use spreadsheet model for testing alternative operations and offered suggestions for features and implementation methods. The author also acknowledges Akin Owosina and Walter Wilcox for allocating budgetary resources to enable completion of model development in the SFWMD's Hydrology and Hydraulics Bureau.

Dr. David Anderson at the SFWMD has been a primary model user and has suggested several useful improvements and new features for testing alternative operations. Dr. Anderson and Dr. Jeff Iudicello, also at the SFWMD, reviewed the draft documentation report and offered many suggestions.

External expert peer reviewers, Dr. Mark Houck, P.E., and Dr. Richard Punnett, P.E., are recognized for their helpful assessments and recommendations to improve both the model and this documentation report.

Special thanks to Natalie Kraft at the SFWMD for applying her outstanding technical editing skills to improve and complete this final document.

EXECUTIVE SUMMARY

Over the past four decades, several regional water resource simulation models, varying in complexity and utility, have been developed by the South Florida Water Management District (SFWMD) for the Upper and Lower Kissimmee Basins. The Upper Kissimmee – Operations Simulation (UK-OPS) Model is a coarse-scale water management simulation model developed to easily and quickly test alternative water operation strategies. Additional model features were created to evaluate the effects of surface water withdrawals based on the draft Kissimmee River and Chain of Lakes Water Reservations rules.

The increasing utility and computational power of Microsoft Excel® made the spreadsheet software program a logical platform to build the UK-OPS Model. The model is a simple, daily timestep, continuous simulation model of the hydrology and operations of the primary lakes in the Upper Kissimmee Basin. Analysts can use the UK-OPS Model to test a variety of operating strategies and receive instant feedback of performance for the primary lake management objectives.

This report describes the purpose, utility, and technical details of the UK-OPS Model. It is not a users' guide, but it is prerequisite reading for analysts who wish to use the model. The UK-OPS Model has been applied to assist with seasonal operations planning, including the SFWMD's monthly Position Analysis, proposed drawdown operations for East Lake Tohopekaliga, and testing the effects of hypothetical surface water withdrawals consistent with the draft Water Reservations rules. Some of these applications are summarized in this report to illustrate appropriate uses of the UK-OPS Model.

The UK-OPS Model and the draft version of this documentation report were peer-reviewed in November 2019. Recommendations for improving the draft documentation report were implemented to complete this final documentation report in March 2020. The model was deemed technically sound, appropriately developed, and usable for the intended applications. The reviewers made some suggestions for improving the model, many of which are under way, particularly the data extension through 2018. The peer-review reports are provided in Appendix D of the main report.

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ACRONYMS AND ABBREVIATIONS

AFET	Alternative Formulation and Evaluation Tool
ALC	Alligator Chain of Lakes
cfs	cubic feet per second
DPA	dynamic position analysis
ET	evapotranspiration
ETO	East Lake Tohopekaliga
GEN	Lake Gentry
GUI	graphical user interface
HMJ	Lakes Hart and Mary Jane
KCH	Lakes Kissimmee, Cypress, and Hatchineha
KRCOL	Kissimmee River and Chain of Lakes
KRRP	Kissimmee River Restoration Project
MPJ	Lakes Myrtle, Preston, and Joel
NGVD29	National Geodetic Vertical Datum of 1929
RF	rainfall
SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model
SPF	standard project flood
TOH	Lake Tohopekaliga
UK-OPS	Upper Kissimmee – Operations Simulation (Model)
UKB	Upper Kissimmee Basin
UKISS	Upper Kissimmee Chain of Lakes Routing Model
WNI	watershed net inflow
WRL	water reservation line

1 INTRODUCTION

The development, application, and maintenance of computer simulation models have been part of the overall strategy adopted by the South Florida Water Management District (SFWMD) to manage the complex water resources in Central and South Florida. Several regional models have been deployed over the past decades to support state and federal planning initiatives, including the Comprehensive Everglades Restoration Plan, the Lower East Coast Water Supply Plan, the Northern Everglades Plan, and Lake Okeechobee Operations Planning efforts.

In 2014, the SFWMD recognized the need for a model that would allow rapid testing and evaluation of alternative water management operations in the Upper Kissimmee Basin (UKB). The primary concern was improvement of the flow regime to the Kissimmee River Restoration Project (KRRP) to better meet restoration targets. Such improvement depends on modification of operations that control water levels in the three largest lakes/lake groups in the UKB: Lakes Kissimmee, Cypress, and Hatchineha (KCH); Lake Tohopekaliga (TOH); and East Lake Tohopekaliga (ETO). To meet this need, the SFWMD developed the Upper Kissimmee – Operations Simulation (UK-OPS) Model. The UK-OPS Model initially was developed using Microsoft Excel® 2013 (v15.0) and has been used for several years by modelers, engineers, and scientists. The model has been modified primarily to increase the options for specifying operations in KCH and to evaluate potential surface water withdrawals consistent with the draft Kissimmee River and Chain of Lakes (KRCOL) Water Reservations rules. The most recent version, and the subject of this report, is UK-OPS (v3.12).

The UK-OPS Model performs daily timestep, continuous simulations of the hydrology and operations of the UKB portion of Central and South Florida's water management system for either period-of-record simulations (continuous 49 years) or position analysis simulations (49 one-year simulations, each with the same initial conditions). It has a run time of approximately 4 minutes.

The UK-OPS Model has some limitations. Hydrologic routing is limited to KCH, TOH, and ETO. The inflow series from the smaller lakes are assumed boundary conditions; thus, operations of those lakes are not simulated. Furthermore, although the UK-OPS Model simulates flows to the Kissimmee River at the S-65 and S-65A structures, it does not simulate the complexity of flows and stages within the Kissimmee River and the Lower Kissimmee Basin. The model does not simulate the rainfall-runoff process, rather it relies on the historical record or a detailed model for simulating lateral inflows to the lakes. Detailed hydraulic computations are not performed; instead, the UK-OPS Model approximates the structure stage-discharge hydraulics. Consequently, the UK-OPS Model is not a replacement for the detailed regional hydrologic and water management simulation models that traditionally have been used for analysis and planning of South Florida's water resources.

Detailed hydrologic models, such as the Regional Simulation Model – Basins (VanZee 2011) and the Mike 11/Mike SHE application to the UKB and Lower Kissimmee Basin (SFWMD 2017), are essential for comprehensive analysis of existing and future components of the water management system. Although detailed regional models are the best available tools for performing finer-scale evaluations, they are not suitable for quickly testing a broad range of alternative operations and/or water withdrawal configurations. The UK-OPS Model complements the more detailed models by screening possible alternatives through rapid simulation and evaluation so the detailed models can focus on fewer, more promising alternatives.

UK-OPS Model input requirements include: 1) regulation schedule zones and release rules for KCH, TOH, and ETO; and 2) daily time series (currently 1965 to 2013) of lake stages, inflows, outflows, and evaporation, which are used with the varying lake surface areas to calculate evapotranspiration (ET) volume. Most of these time-series inputs come from historical data or simulated values from detailed regional models.

UK-OPS Model outputs include: 1) typical hydrologic model outputs for the primary lakes—yearly water budgets, daily stage and discharge hydrographs to facilitate in-depth comparative analyses, stage and flow duration curves, and stage and flow percentile plots; and 2) hydrologic performance indicators to summarize and compare key measures among alternative plans/scenarios—reduction in annual mean flow at S-65 to evaluate impacts on the proposed KRCOL Water Reservations, water supply withdrawal reliability, and summaries of maximum stages occurring for user-specified durations.

This report provides readers with a broad view of the basic capabilities and limitations of the UK-OPS Model as well as the details of the algorithms used to simulate the hydrology and water management of the system. This report is not intended to be a comprehensive user's manual for appropriate use of the model and does not contain that level of detail. Furthermore, because initial development of the UKOPS Model focused on immediate applications, efforts were not spent on making the model user-friendly. The model does not contain limits on parameter values or warnings to caution users when results may not be realistic; therefore, the model should be used with substantial professional judgement. Future development efforts may expand and improve the user interfaces. Reading this document is necessary to understand the UK-OPS Model. To use the UK-OPS Model in its current form, interactive training may be necessary.

The need to document and peer review the UK-OPS Model arose in 2019 during the planning effort for the proposed KRCOL Water Reservations rule. Preparation of the draft report was expedited by the Modeling Section of the Hydrology and Hydraulics Bureau of the SFWMD. Recommendations from the formal external peer review were implemented and are reflected in this final report.

This report is organized into the following sections:

1. *Introduction* – A broad summary of the UK-OPS Model and the purpose and structure of this report.
2. *System Hydrology: Water Budget Approach* – An overview of the model domain, system interconnectivity, and the subsystem components, using diagrams and the continuity equation. Data needs and sources also are presented.
3. *Water Management Operating Rules* – The regulation schedules and release rules for the primary lakes: KCH, TOH, and ETO. Options for changing operating regimes also are described.
4. *Model Structure and Organization* – An overview of the organization of the worksheets; explanations of each primary worksheet, including user interfaces; and the general data flow between worksheets.
5. *Model Output* – Various graphical and tabular display summaries of simulated performance that enable evaluation of the simulations.
6. *Model Validation* – Comparison of the UK-OPS Model output with historical data to demonstrate the accuracy of the routing algorithms.
7. *Applications* – UK-OPS Model implementations, including the monthly Position Analysis and scenarios examined to support the proposed KRCOL Water Reservations. These applications represent typical appropriate uses of the UK-OPS Model.
8. *Summary and Recommendations* – Summary of model strengths and limitations and suggestions for future enhancements to improve model accuracy and utility.

2 SYSTEM HYDROLOGY: WATER BUDGET APPROACH

The UK-OPS Model uses a simple water balance approach to simulate the water levels and discharges for the primary hydrologic components of the larger lake systems in the UKB (**Figure 2-1**). This section presents an overview of the system simulated by the model, the subsystems, and their interactions. Also described in this section are the details of the hydrologic components for each subsystem. The specific operating rules and routing procedures used by the UK-OPS Model are presented in **Sections 3** and **4**, respectively.

2.1 System Overview

The SFWMD is the largest of the five water management districts created in 1972 by the Florida Water Resources Act (Chapter 373, Florida Statutes). Within the SFWMD boundaries, from Orlando to the Florida Keys, are 18,000 square miles and a current (2019) population of more than 8.7 million residents. The SFWMD oversees the water resources of the region, and its primary responsibilities include regional flood control, water supply, water quality protection, and ecosystem restoration.

The UKB is the northernmost watershed in the SFWMD and is the headwaters to the Kissimmee-Okeechobee-Everglades ecosystem. Within the UKB, the SFWMD manages the water levels in seven groups of lakes; the three largest are KCH, TOH, and ETO (**Figure 2-1**). Water is discharged from the UKB at S-65 to manage water levels in the upstream lakes and to provide flow to the Kissimmee River and the KRRP. Except for very dry periods, the flow at S-65 eventually is discharged to Lake Okeechobee via S-65E. The S-65A structure receives runoff from the basin bounded by S-65 to S-65A and is the structure regulating inflow to the KRRP. Thus, the operation of S-65A is also important to the KRRP.

The UK-OPS Model simulates the primary water budget components for KCH, TOH, and ETO within the UKB. **Sections 2.2** to **2.4** describe the methodology used by the model for these lakes. **Section 2.5** describes the simulation methodology used by the current version of the UK-OPS Model for the smaller lake systems.

Figure 2-2 shows the flow paths through the UKB Chain of Lakes and the associated water control structures that serve as outlets from each lake or lake system. Outflows from the northern branch of the chain via TOH at S-61 flow to Cypress Lake, which also receives outflow from the eastern branch of the chain from Lake Gentry (GEN) via S-63A. Outflow from Cypress Lake travels through Lake Hatchineha to Lake Kissimmee, which is the largest lake in the UKB. Water from Lake Kissimmee is released to the Kissimmee River via S-65.

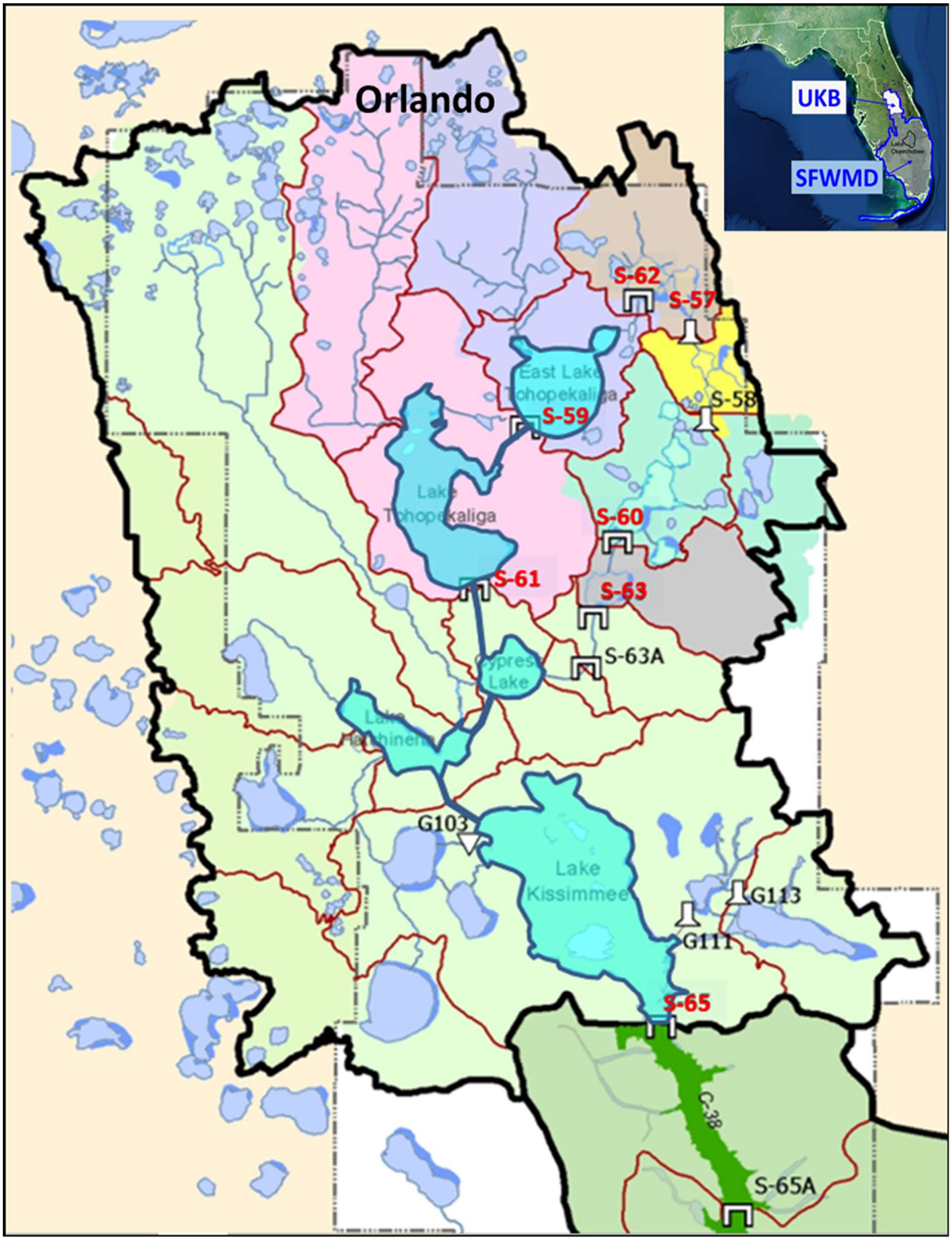


Figure 2-1. Map of the Upper Kissimmee Basin, highlighting the larger lake systems: East Lake Tohopekaliga (ETO), Lake Tohopekaliga (TOH), and Lakes Kissimmee, Cypress, and Hatchineha (KCH).

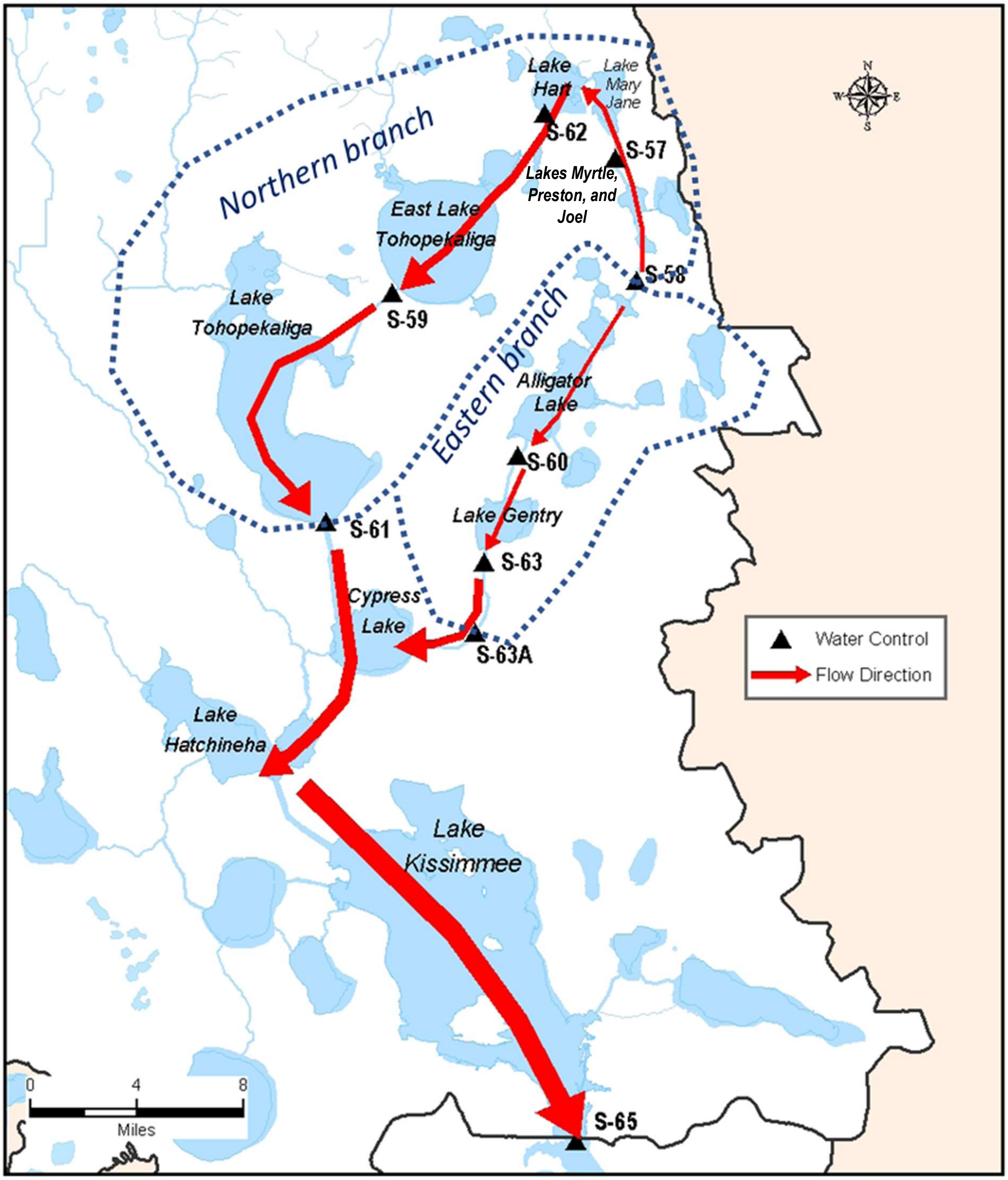


Figure 2-2. Flow paths for the Upper Kissimmee Basin Chain of Lakes.

Figure 2-3 shows the primary user interface of the UK-OPS Model, a Microsoft Excel® application that enables the user to set-up a modeling scenario, run it, and automatically generate numerous post-simulation outputs. The majority of output summaries, including performance summary graphics, can be accessed via this interface. The map is interactive and allows selection of the lake systems to be included in the simulation. The Simulation Scenario Manager allows the user to select the simulation type (continuous or position analysis) and to retrieve and/or run up to four scenarios.

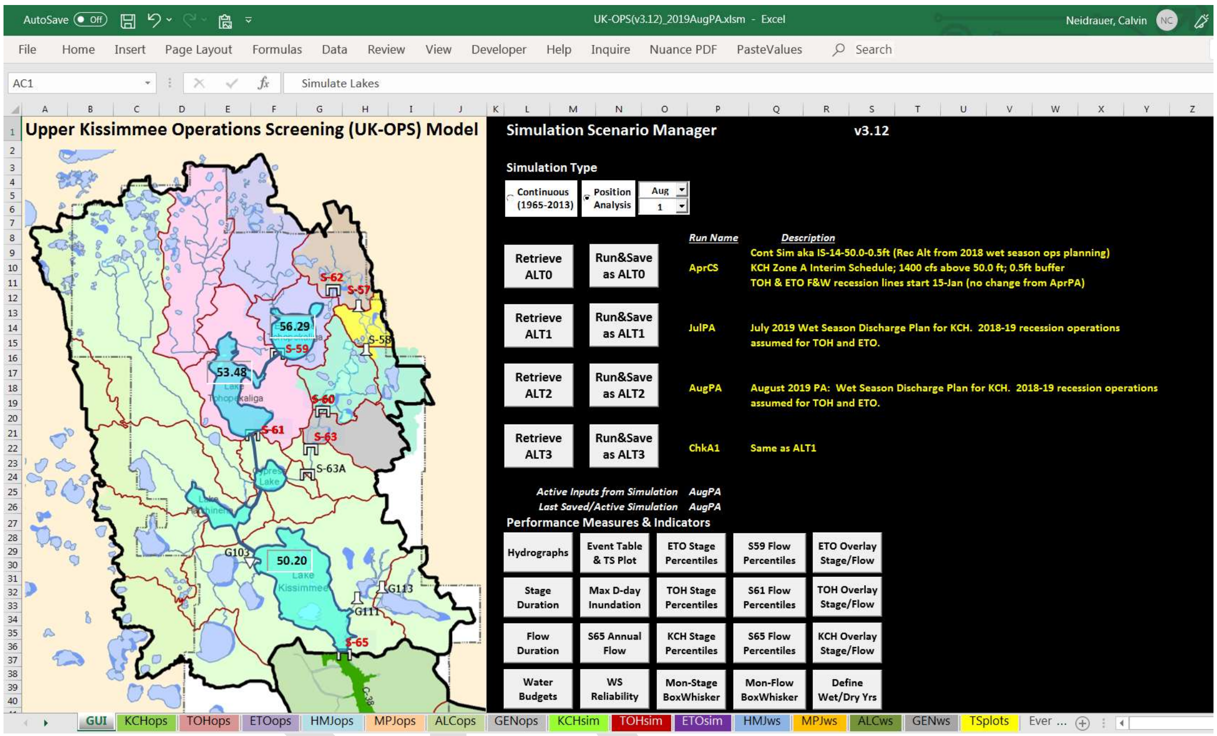


Figure 2-3. User Interface for the Upper Kissimmee – Operations Simulation (UK-OPS) Model.

The remainder of **Section 2** provides a general description of the main water bodies (East Lake Tohopekaliga, Lake Tohopekaliga, Lakes Kissimmee-Cypress-Hatchineha, and the Kissimmee River) and the derivations of the routing, or continuity equations used by the UK-OPS Model. The smaller lakes in the UKB are partially simulated by the UK-OPS Model. Routing is not performed for the smaller lakes in the current version of the model. **Section 2.5** describes the features of the smaller lakes that are included.

2.2 East Lake Tohopekaliga

ETO is the northernmost of the three largest lake systems in the UKB. At the highest stage allowed by the regulation schedule (i.e., winter pool elevation) of 58.0 feet National Geodetic Vertical Datum of 1929 (NGVD29), the surface area of ETO is approximately 12,900 acres. Inflows are from the ETO drainage basin, including Boggy Creek and its drainage basin to the north. Managed inflows via the S-62 gated spillway are from Lakes Hart and Mary Jane (HMJ) to the northeast. Managed outflows are via the S-59 gated spillway, which flows southwest to TOH.

The continuity equation used by the UK-OPS Model to describe the ETO water budget is as follows (and graphically displayed in **Figure 2-4**):

$$\Delta S = RF - ET + WNI + S62 - S59 - [WS] \tag{2.2.1}$$

Where the terms of the water budget (in acre-feet per day) are defined as:

ΔS = change in lake storage

RF = rainfall volume over lake surface area (lumped with WNI)

ET = evapotranspiration volume over variable lake surface area

WNI = watershed net inflow (WNI lumps all other terms of the water budget, including tributary inflows, overland flow, groundwater fluxes, and other inflows and outflows assumed to not change in the simulations.)

S62 = inflow from upstream HMJ

S59 = simulated outflow from ETO

[WS] = optional simulated water supply withdrawal from ETO

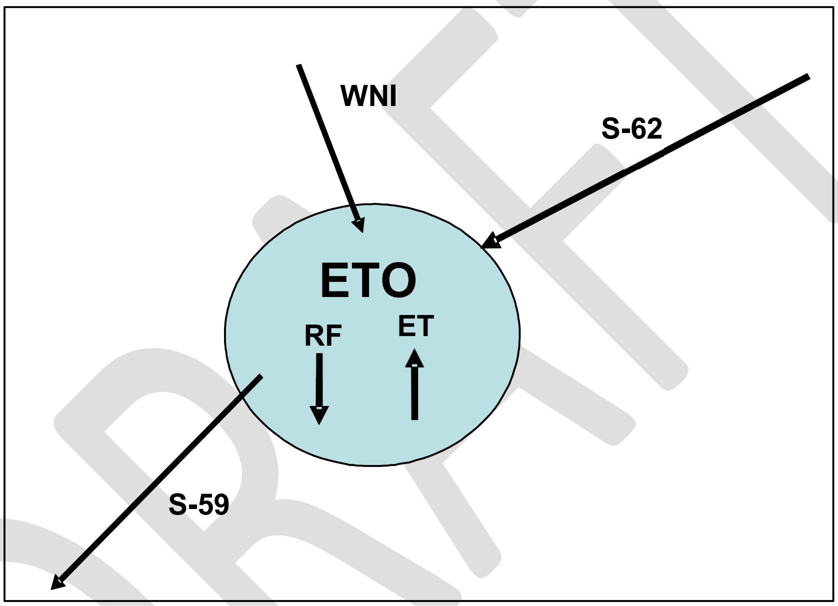


Figure 2-4. East Lake Tohopekaliga water budget components simulated by the UK-OPS Model.

The UK-OPS Model simulates S-59 releases, ET, storage change, and corresponding lake stage using the stage-storage relationship. In the current model, S-62 is an inflow boundary condition based on historical flow data. WNI+RF is an assumed persistent time series for each simulation and an input to the model. The WNI+RF values are preprocessed from historical flow data or from a detailed hydrologic simulation model like the Mike 11/Mike SHE (SFWMD 2017). Based on the continuity equation, and by knowing all the remaining terms of the water budget, WNI+RF can be computed as follows (with WS = 0):

$$\Delta S = (WNI + RF) - ET + S62 - S59$$

Solving this equation for WNI+RF yields:

$$WNI + RF = \Delta S + ET - S62 + S59 \qquad (2.2.2)$$

Where all terms are daily volumes obtained from historical data or the supporting, detailed hydrologic model and are defined as follows:

WNI+RF = watershed net inflow plus rainfall volume over the lake surface area; calculated once and assumed to be a persistent time series for each simulation

$\Delta S = S(h_{t+1}) - S(h_t)$ = change in lake storage during the daily time step; calculated using lake stages and the lake stage-storage relationship

$ET = et_t \cdot A(h_{t-1})$ = evapotranspiration volume; where et_t is the daily evapotranspiration depth and $A(h_{t-1})$ is the lake surface area for the previous day calculated using the lake stage-area relationship

S62 = inflow from upstream HMJ

S59 = outflow from ETO

Once the WNI+RF series is calculated, it is unchanged for UK-OPS Model runs, which simulates the other water budget terms using **Equation 2.2.1**.

2.3 Lake Tohopekaliga

TOH is the second largest lake system in the UKB. At winter pool elevation of 55.0 feet NGVD29, the surface area is approximately 22,000 acres. Inflows are from the TOH drainage basin, including Shingle Creek and its drainage basin to the north. Managed inflows via the S-59 gated spillway are from ETO to the northeast. Managed outflows are via the S-61 gated spillway, which flows south to Cypress Lake.

The continuity equation used by the UK-OPS Model to describe the TOH water budget is as follows (and graphically displayed in **Figure 2-5**):

$$\Delta S = RF - ET + WNI + S59 - S61 - [WS] \tag{2.3.1}$$

Where the terms of the water budget (in acre-feet per day) are defined as:

ΔS = change in lake storage

RF = rainfall volume over lake surface area (lumped with WNI)

ET = evapotranspiration volume over variable lake surface area

WNI = watershed net inflow (WNI lumps all other terms of the water budget, including tributary inflows, overland flow, groundwater fluxes, and other inflows and outflows assumed to not change in the simulations.)

S59 = simulated inflow from upstream ETO

S61 = simulated outflow from TOH

[WS] = optional simulated water supply withdrawal from TOH

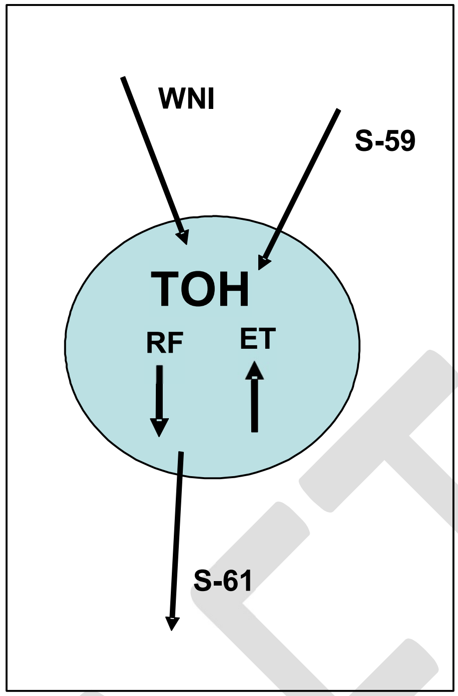


Figure 2-5. Lake Tohopekaliga water budget components simulated by the UK-OPS Model.

The UK-OPS Model simulates all the water budget components except RF and WNI, which are added to become the term WNI+RF. WNI+RF is an assumed, persistent time series for each simulation and is an input to the model. The WNI+RF values are preprocessed from historical flow data or from a detailed hydrologic simulation model like the Mike 11/Mike SHE (SFWMD 2017). Based on the continuity equation, and by knowing all the remaining terms of the water budget, WNI+RF can be computed as follows (with WS = 0):

$$\Delta S = (WNI + RF) - ET + S59 - S61$$

Solving this equation for WNI+RF yields:

$$WNI + RF = \Delta S + ET - S59 + S61 \tag{2.3.2}$$

Where all terms are daily volumes obtained from historical data or the supporting, detailed hydrologic model and are defined as follows:

WNI+RF = watershed net inflow plus rainfall volume over the lake surface area; calculated once and assumed a persistent time series for each simulation

$\Delta S = S(h_{t+1}) - S(h_t)$ = change in lake storage during the daily time step; calculated using lake stages and the lake stage-storage relationship

$ET = et_t \cdot A(h_{t-1})$ = evapotranspiration volume; where et_t is the daily evapotranspiration depth and $A(h_{t-1})$ is the lake surface area for the previous day calculated using the lake stage-area relationship

S59 = inflow from upstream ETO

S61 = outflow from TOH

Once the WNI+RF series is calculated, it is unchanged for UK-OPS Model runs, which simulates the other water budget terms using **Equation 2.3.1**.

2.4 Lakes Kissimmee, Cypress, and Hatchineha

KCH is the largest of the lake systems in the UKB. The three lakes of the KCH system are operated as a single water body because there are no intermediate water control structures in the system. The UK-OPS Model simulates the system as a single lake. At the current winter pool elevation of 52.5 feet NGVD29, the surface area is approximately 61,000 acres. Inflows are from the KCH drainage basins, including Reedy Creek and its drainage basin to the north. Managed inflows are from TOH to the northeast via the S-61 gated spillway and from eastern portion of the UKB Chain of Lakes via S-63A. Managed outflows from KCH are via the S-65 gated spillway, which flows south to the Kissimmee River.

The continuity equation used by the UK-OPS Model to describe the KCH water budget is as follows (and graphically displayed in **Figure 2-6**):

$$\Delta S = [RF + WNI + S63A] - ET + S61 - S65 \qquad (2.4.1)$$

Where the terms of the water budget (in acre-feet per day) are defined as:

ΔS = change in lake storage

RF = rainfall volume over lake surface area (lumped with WNI)

ET = evapotranspiration volume over variable lake surface area

WNI = watershed net inflow (WNI lumps all other terms of the water budget, including tributary inflows, overland flow, groundwater fluxes, and other inflows and outflows assumed to not change in the simulations.)

S61 = simulated inflow from upstream TOH

S63A = boundary condition inflow from GEN and the southeastern portion of the UKB Chain of Lakes (Note: This term is assumed to not change with the simulations. It is not explicitly used and is implicitly part of WNI.)

S65 = simulated outflow to the Kissimmee River

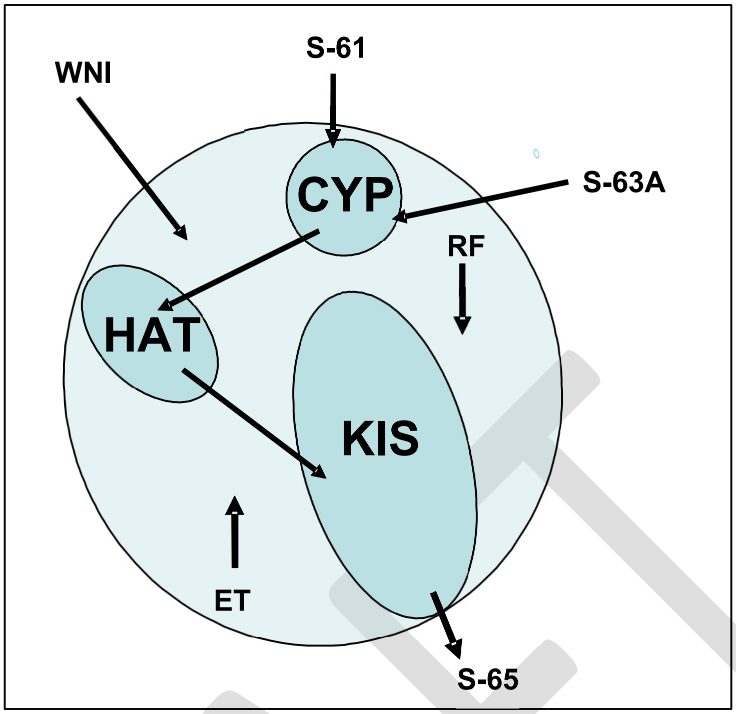


Figure 2-6. Lakes Kissimmee, Cypress, and Hatchineha (KCH) water budget components simulated by the UK-OPS Model.

The UK-OPS Model simulates all the water budget components except for S-63A, RF, and WNI. Flow from S-63A is a boundary condition. S-63A flow is assumed to be the same as historical, or the same as that simulated by the detailed hydrologic model (e.g., the Mike 11/Mike SHE). RF and WNI are added to become the term WNI+RF, which is an assumed, persistent time series for each simulation and is an input to the model. The WNI+RF values also are preprocessed from historical flow data or from the supporting, detailed hydrologic simulation model. Based on the continuity equation, and by knowing all the remaining terms of the water budget, WNI+RF is computed as follows:

$$\Delta S = (WNI + RF) - ET + S61 - S65 \text{ (S63A is part of WNI)}$$

Solving this equation for WNI+RF yields:

$$WNI + RF = \Delta S + ET - S61 + S65 \qquad (2.4.2)$$

Where all terms are daily volumes obtained from historical data or the supporting, detailed hydrologic model and are defined as follows:

WNI+RF = watershed net inflow plus rainfall volume over the lake surface area; calculated once and assumed a persistent time series for each simulation

$\Delta S = S(h_{t+1}) - S(h_t)$ = change in lake storage during the daily time step; calculated using lake stages and the lake stage-storage relationship

$ET = et_t \cdot A(h_{t-1})$ = evapotranspiration volume; where et_t is the daily evapotranspiration depth and $A(h_{t-1})$ is the lake surface area for the previous day calculated using the lake stage-area relationship

S61 = inflow from TOH

S65 = outflow to the Kissimmee River

Once the WNI+RF series is calculated, it is unchanged for UK-OPS Model runs, which simulates the other water budget terms using **Equation 2.4.1**.

2.5 Small Lakes in the Upper Kissimmee Basin

This section describes the approach used in the UK-OPS Model for the small lakes that are connected and contribute inflow to the larger lake systems described in **Sections 2.2** to **2.4**. The small lake systems include HMJ; Lakes Myrtle, Preston, and Joel (MPJ); the Alligator Chain of Lakes (ALC); and GEN. **Figure 2-2** shows the flow paths and proximity of the small lake systems to the larger systems. **Figure 2-7** shows how the smaller lake systems connect to the larger systems.

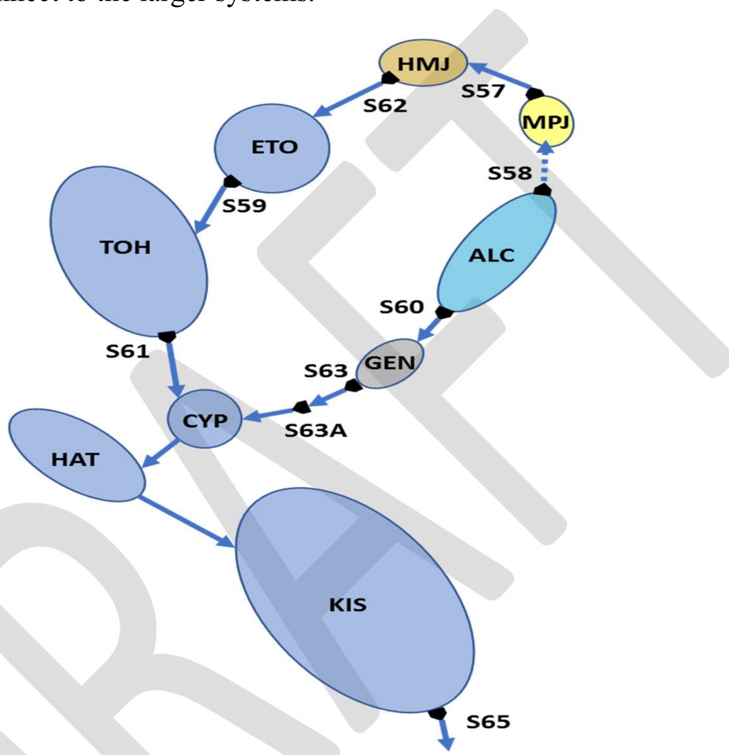


Figure 2-7. Small lake systems and their connections to the large lake systems in the Upper Kissimmee Basin.

Outflows from the small lakes generally end up in Lake Cypress. Outflows from ALC can move south via the S-60 gated spillway or north via the S-58 gated culvert. For larger flows, the southern route typically is used because it has higher capacity. The model does not simulate outflows from the small lakes. However, for evaluating water supply withdrawals from the small lakes, the model assumes flows from ALC and GEN are to Lake Cypress (KCH system) and flows from MPJ and HMJ are to ETO.

The UK-OPS Model partially simulates the small lake systems; no routing is performed for these lakes. For operations planning simulations, which usually involve only the larger lakes, the hydrology of the small lake systems is not important because the outflows from these lakes are implicitly part of the WNI term. For evaluating proposed surface water withdrawal scenarios subject to the draft KRCOL Water Reservation rules, an approximation was made, as described below.

The draft KRCOL Water Reservation rules were designed to allow water supply withdrawals to occur when they do not adversely impact the water resources and associated ecology of the lake systems and the KRRP. The rules basically define constraints that determine when water supply withdrawals can occur.

To evaluate the effects of surface water withdrawals under the draft KRCOL Water Reservation rules, the UK-OPS Model compared the small lake stage series with the water reservation line (WRL) (**Section 4.3**). If the lake stage is above the WRL and the other rule criteria are met, then water supply withdrawals can occur. Recognizing the withdrawal may reduce outflow from the small lake system and affect the downstream large lake system, the UK-OPS Model assumes the withdrawal is directly from the downstream large lake system. Therefore, for withdrawals from MPJ and/or HMJ, the simulation determines the timing of the withdrawal using the stage and WRL of the small lake but makes the withdrawal from ETO. And for withdrawals from ALC and/or GEN, the simulation determines the timing of the withdrawal using the stage and WRL of the small lake but makes the withdrawal from KCH.

This simplifying assumption, to make the withdrawal from the next downstream large lake, was made for expediency and with recognition that building full routing capability for four more lake systems would add significantly to the computational burden of this Microsoft Excel® model. Building routing capability for the small lakes is a possible future improvement to the UK-OPS Model, but the likely minor increased benefit should be weighed with the increased computational burden and slower run times.

3 WATER MANAGEMENT OPERATING RULES

3.1 Overview

The UK-OPS Model simulates the management of releases from the larger lake systems in the UKB using rules that mimic the regulation schedules and associated release guidance criteria. This section describes these rules and their implementation in the model. Also presented in this section are some of the options built into the model for simulating alternative release strategies.

3.2 East Lake Tohopekaliga Regulation Schedule

The ETO regulation schedule (**Figure 3-1**) specifies releases at S-59 based on lake stage. The ETO regulation schedule rules traditionally have been designed to simply discharge water whenever the lake stage is above the schedule (Zone A). Releases in Zone B can be made for environmental purposes, navigation, and water supply, but are not necessary to manage the lake stage.

Figure 3-2 illustrates the ETO regulation schedule as seen by the UK-OPS Model. Up to six zones can be defined. The zones are numbered, and the labeled lines represent the bottom of each zone. The green line (Zone 4) represents the drawdown operation used in 2018 and 2019 to benefit in-lake fish and wildlife resources. The drawdowns initiated at an elevation of 57.60 feet NGVD29 on January 15. The dashed line (Zone 6) represents a 0.3-foot offset above the Zone A line (Zone 5) that can be used to transition flows up to the maximum discharge. The model can simulate a linear transition from zero to maximum discharge in this range, if specified.

The UK-OPS Model uses a zone-discharge function to specify discharge rates within the regulation schedule zones. Consistent with the regulation schedule zone labeling, the zone-discharge function places the zone number at the bottom of the zone. For ETO (**Figure 3-3**), the function is relatively simple. Zero discharge for all zones below Zone 4. Within Zone 4 (between the green line and the Zone 5 black line in **Figure 3-2**), discharge linearly increases with stage from 750 to 1,300 cubic feet per second (cfs). Above Zone 5, continue with 1,300 cfs, which is the maximum S-59 capacity assumed by the model. In this case, there is no transition specified for Zone 5. For stages above the Zone 5 line (same as bottom of Zone A), the model simulates the maximum hydraulic capacity of S-59, considering the headwater and tailwater stages approximated by the simulated stages in ETO and TOH, respectively. Note from **Figure 3-1**, the stated S-59 design capacity is 820 cfs, which is less than the 1,300 cfs maximum capacity in **Figure 3-3**.

The standard project flood (SPF) discharge rate for S-59 is 1,300 cfs, which can be reached under high stage conditions. The model simulates this capability even though it exceeds the design, which is based on 30% of the SPF discharge rate.

UK-OPS Model users can specify the breakpoints of the ETO regulation schedule and the zone-discharge function by changing the values in the color-coded tables within the ETOops worksheet. The regulation schedule and the zone-discharge function graphics automatically display changes to the inputs to enable verification of the intended changes.

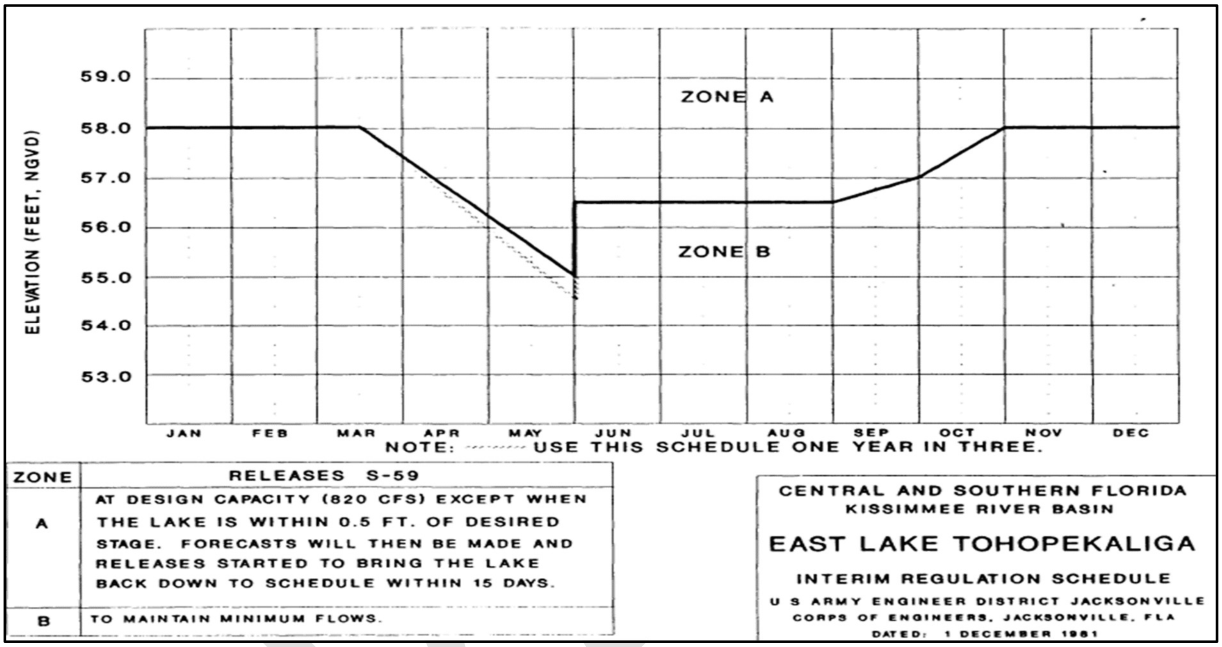


Figure 3-1. East Lake Tohopekaliga regulation schedule.

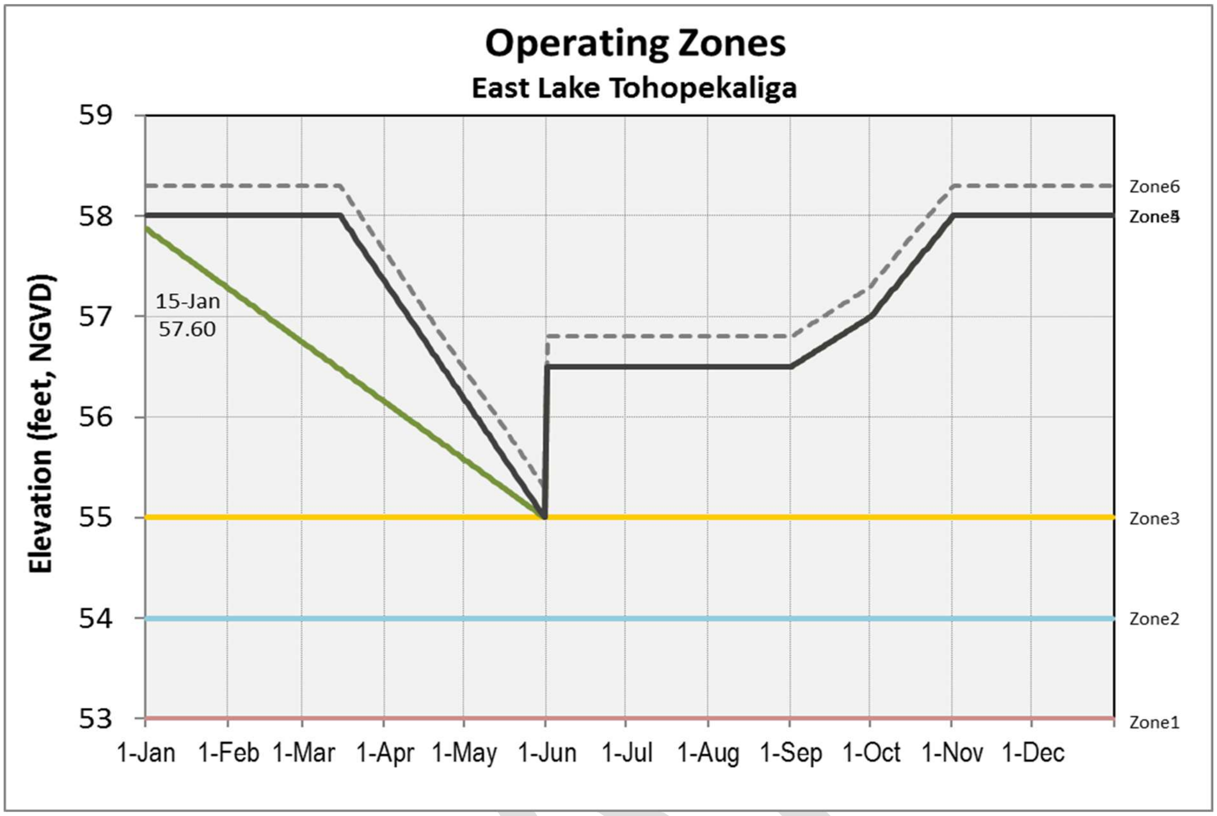


Figure 3-2. East Lake Tohopekaliga regulation schedule as seen by the UK-OPS Model.

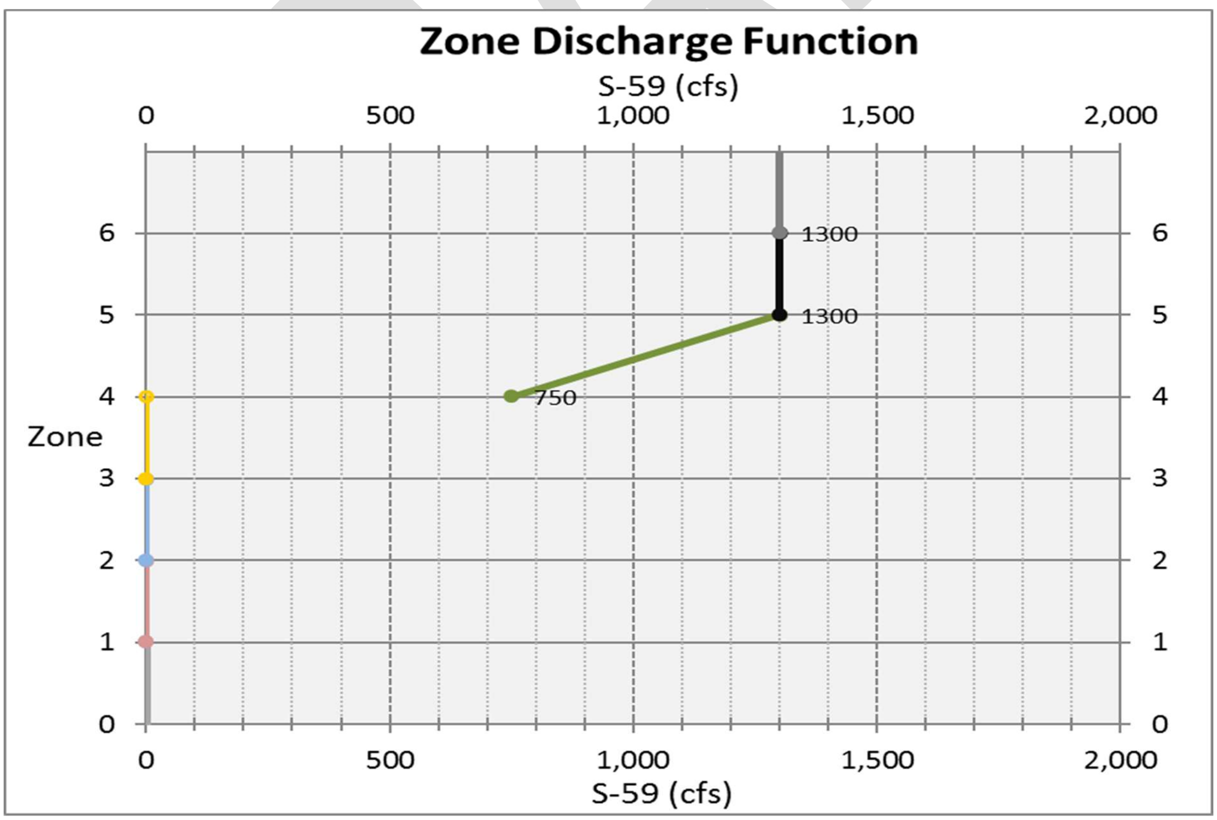


Figure 3-3. East Lake Tohopekaliga zone discharge function used by the UK-OPS Model.

3.2.1 Hydraulic Capacity Assumptions for S-59

The S-59 single-gated spillway capacity (100% of the SPF) of 1,300 cfs occurs at the SPF headwater and tailwater stages. Real system operations must account for various factors to determine the appropriate spillway gate opening and discharge rate, including maximum allowable gate opening (MAGO) criteria to keep discharge velocities from exceeding design limits and maximum permissible head (MPH) across the structure. These criteria are not explicitly considered by the daily timestep routing model, but the model does calculate the upper limit of S-59 discharge capability (S59Qcap) using the daily simulated upstream and downstream lake stages, which is capped by the user-input S59maxcap, currently set to 1,300 cfs.

The S-59 discharge capacity (1,300 cfs) also is the 99^{th} percentile value of the historical flow data (1965 to 2005). Maximum flow during the historical period was 2,160 cfs; however, this maximum is not recommended for S59maxcap because it is excessively high and inappropriate as an upper limit for simulating long-term performance. If flood peaks are of interest, more refinement to the model or a finer timestep hydraulic model may be needed.

Details about the daily S-59 hydraulic capacity computation (S59Qcap) are contained within the ETOops and ETOsim worksheets and are described below.

S59Qcap is the structure's hydraulic capacity, which is approximated by the UK-OPS Model as:

$$\text{S59Qcap} = \text{K}(HWEL - CEL)\sqrt{HWEL - TWEL} \qquad (3.2.1)$$

Where:

HWEL = S59Hsim

CEL = 49.1 feet crest elevation

TWEL = S61Hsim

K = 125, derived from the following traditional orifice flow equation:

$$\text{Q} = \text{CA}\sqrt{2g(HWEL - TWEL)} \qquad (3.2.2)$$

Where:

C = empirical discharge coefficient

A = L(HWEL-CEL)

g = gravity of Earth (32.2 ft/s^2)

L = gate width

By taking the ratio of Q/Q*, where Q* is the same equation using the SPF information, **Equation 3.2.1** can be derived. **Equation 3.2.1** is used by the UK-OPS Model for daily timestep approximation of the dynamic structure capacity. As described previously, S59Qcap cannot be larger than S59maxcap, which currently is set to the SPF capacity of 1,300 cfs.

3.2.2 Temporary Pump Capacity Assumptions for S-59

For testing scenarios such as ETO stage drawdown operations, which aim to periodically lower the lake stage below the elevation of the downstream TOH, the UK-OPS Model has a feature that allows specification of temporary pumps in parallel with the S-59 gated spillway. The ETOops worksheet allows specification of the average daily pump flow rate (S59pumpcap) and has an option to supplement gravity releases with pumping when the spillway capacity is less than the target release. Simultaneous gravity flow and pumping are simulated, and the user can specify a percent reduction in gravity capacity when pumping is used simultaneously. This accounts for the reduced spillway discharge rate due to the rise in tailwater stage from pumping (**Figure 3-4**). Such a condition can happen when the water level difference across the structure (Δh) is small but positive. Thus, gravity flow capability is possible, but it may be smaller than desired, and pumping is necessary to meet the desired flow target. Such a simultaneous use condition may be short-lived as the headwater elevation recedes below the tailwater elevation and water level difference across the structure becomes negative.

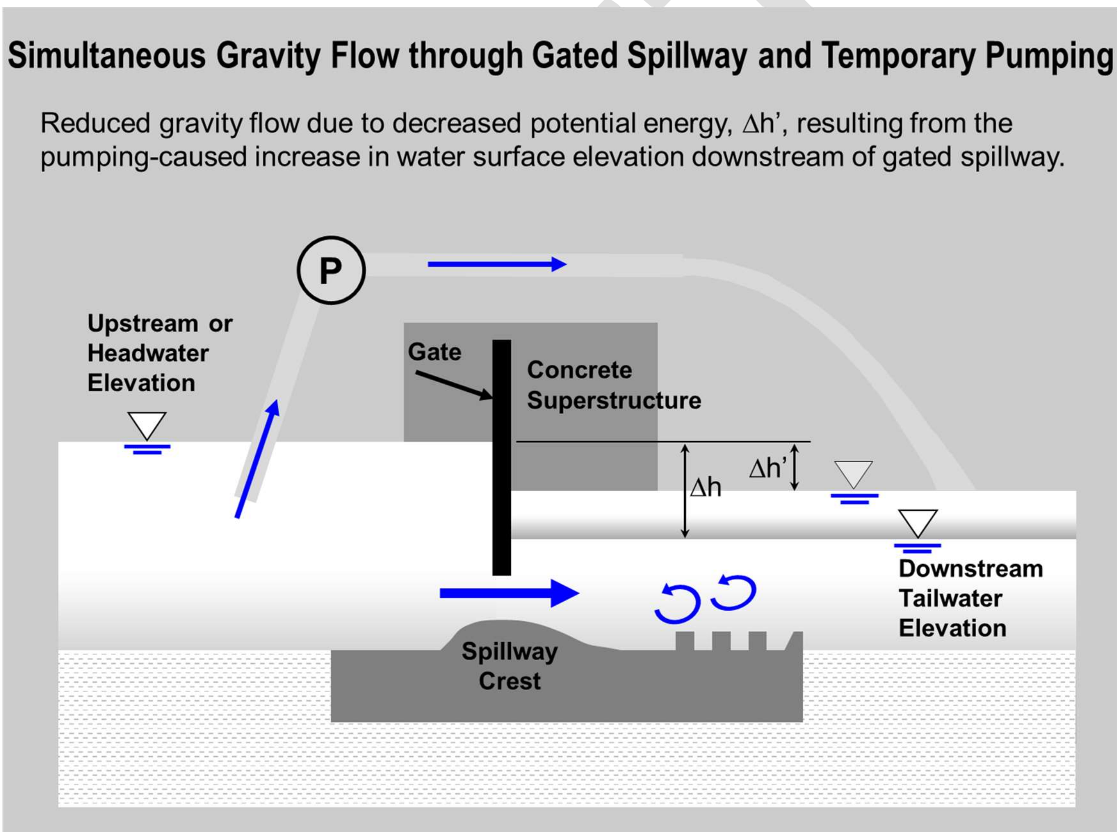


Figure 3-4. Simultaneous gated spillway gravity flow and temporary pumping.

3.2.3 Options for Simulating S-59 Operations

The UK-OPS Model has a few ways to simulate S-59 releases, which allows for testing alternative operations. **Table 3-1** shows the various settings of the parameter QoptETO, which is specified in the ETOops worksheet.

Table 3-1. Optional UK-OPS Model operations for S-59 and East Lake Tohopekaliga.

Parameter	Definition
QoptETO = 0	Flow values set to inputs for testing routing calculations
QoptETO = 1	Releases per operating zones and zone-discharge function
QoptETO = 2	Same as Option 1 but gravity releases are supplemented with pumping when the spillway capacity is less than the target release (Qregadj).
QoptETO = 3	Fixed, unrealistic 200 cubic feet per second release [placeholder for future option and code in routing worksheet (ETOsim)]
QoptETO = 4	Releases per user-specified logic in routing worksheet (ETOsim) Currently set up to determine releases necessary to achieve user-specified stage recession rates within user-specified dates

3.3 Lake Tohopekaliga Regulation Schedule

The TOH regulation schedule (**Figure 3-5**) specifies releases at S-61 depending on lake stage. The TOH regulation schedule rules traditionally have been designed to simply discharge water whenever the lake stage is above the schedule (Zone A). Releases in Zone B can be made for environmental purposes, navigation, and water supply, but are not necessary to manage the lake stage.

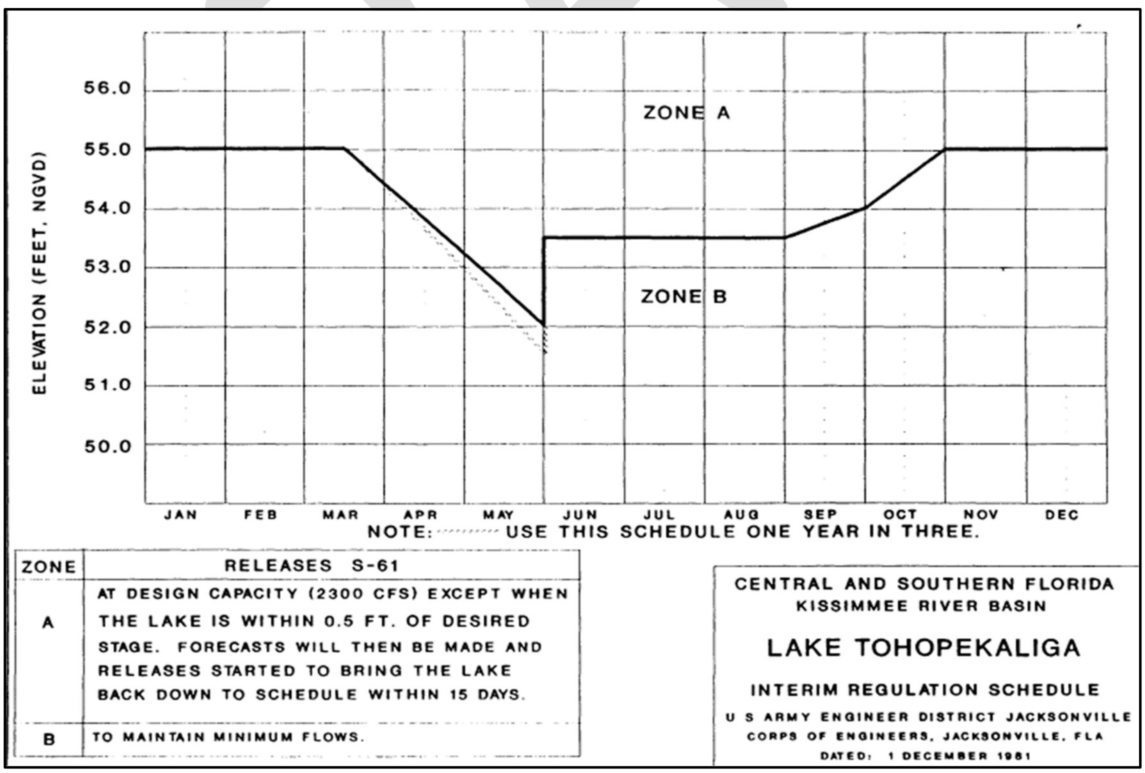


Figure 3-5. Lake Tohopekaliga regulation schedule.

Figure 3-6 illustrates the TOH regulation schedule as seen by the UK-OPS Model. Up to six zones can be defined. The zones are numbered, and the labeled lines represent the bottom of the zone. The green line (Zone 4) represents the drawdown operation used in 2018 and 2019 to benefit in-lake fish and wildlife resources. The drawdowns initiated at an elevation of 54.60 feet NGVD29 on January 15. The dashed line (Zone 6) represents a 0.3-foot offset above the Zone A line (Zone 5) that can be used to transition flows up to the maximum discharge. The model can simulate a linear transition from zero to maximum discharge in this range, if specified.

The UK-OPS Model uses a zone-discharge function to specify discharge rates within the regulation schedule zones. Consistent with the regulation schedule zone labeling, the zone-discharge function places the zone number at the bottom of the zone. For TOH (**Figure 3-7**), the function is relatively simple. Zero discharge for all zones below Zone 4. Within Zone 4 (between the green line and the Zone 5 black line in **Figure 3-6**), discharge linearly increases with stage from 1,150 to 2,300 cfs. Above Zone 5, continue with 2,300 cfs, which is the maximum S-61 capacity assumed by the model. In this case, there is no transition specified for Zone 5. For stages above the Zone 5 line (same as bottom of Zone A), the model simulates the maximum hydraulic capacity of S-61, considering the headwater and tailwater stages approximated by the simulated stages in TOH and KCH, respectively.

UK-OPS Model users can specify the breakpoints of the TOH regulation schedule and the zone-discharge function by changing the values in the color-coded tables within the TOHops worksheet. The regulation schedule and the zone-discharge function graphics automatically display changes to the inputs to enable verification of the intended changes.

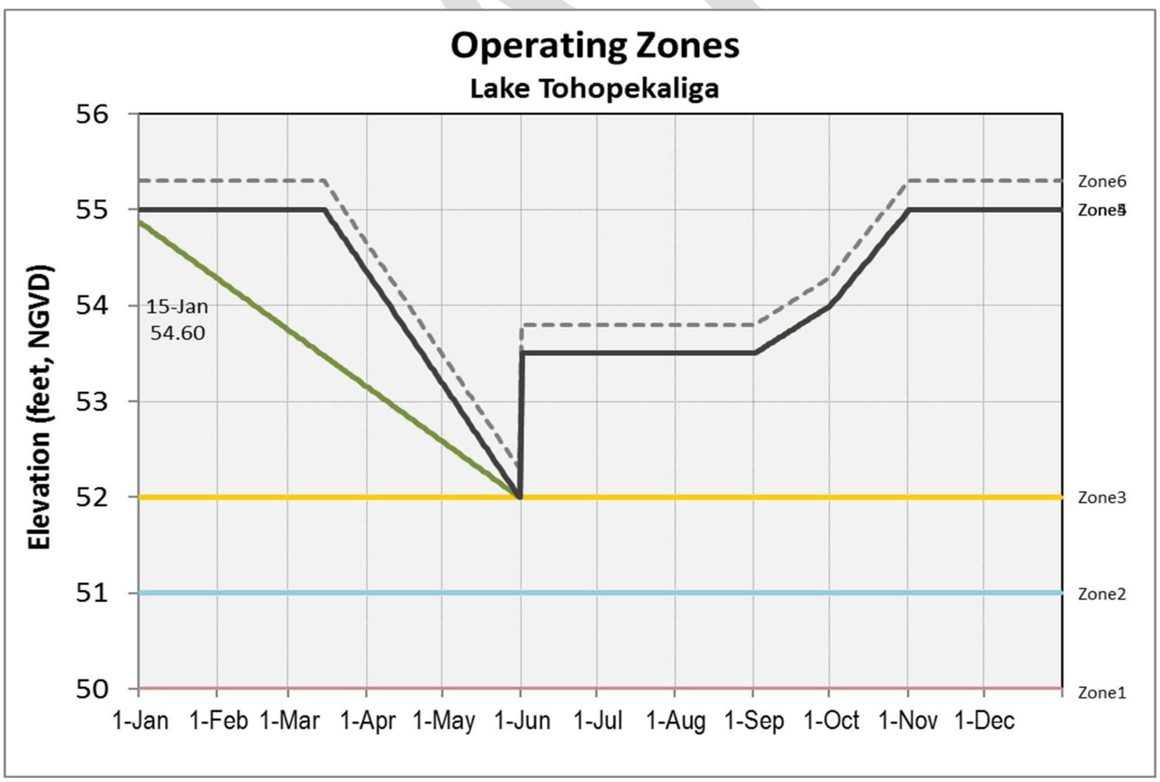


Figure 3-6. TOH regulation schedule as seen by the UK-OPS Model.

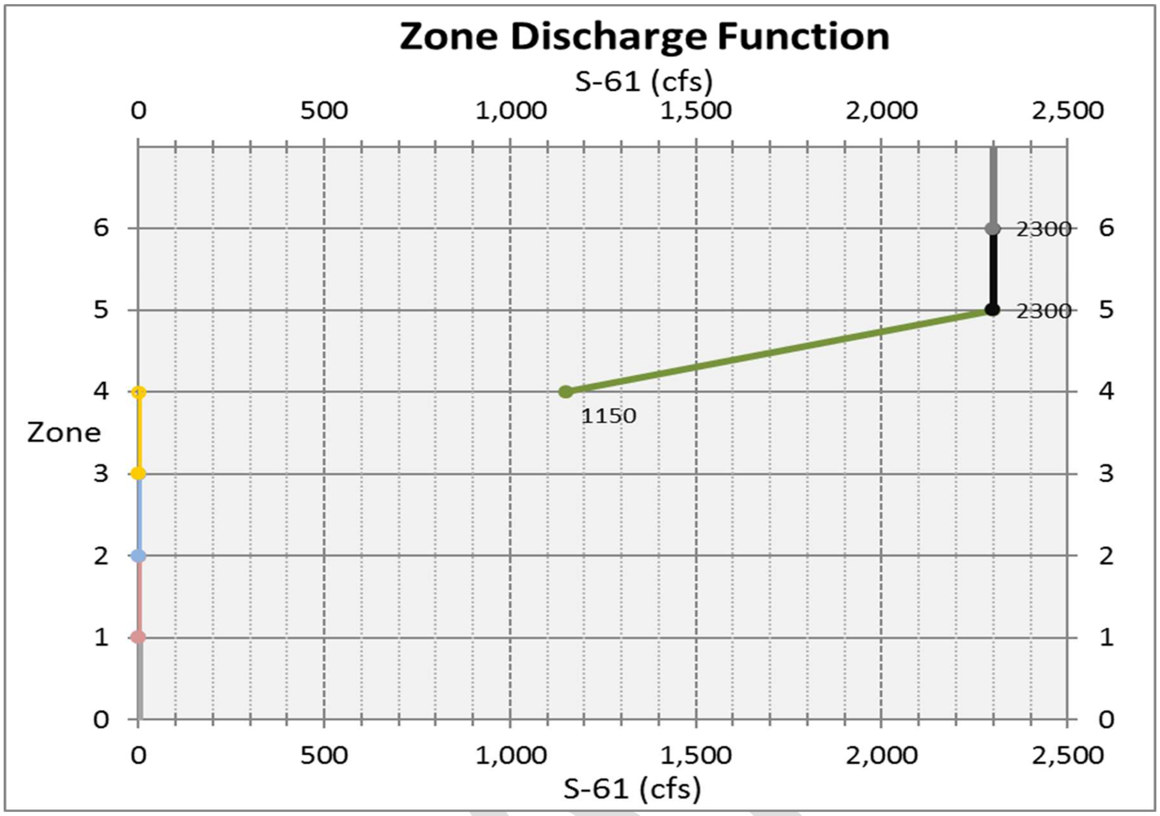


Figure 3-7. TOH zone discharge function used by the UK-OPS Model.

3.3.1 Hydraulic Capacity Assumptions for S-61

The S-61 single-gated spillway has a design capacity of 2,300 cfs at the design headwater and tailwater stages. Real system operations must account for various factors to determine the appropriate spillway gate opening and discharge rate, including maximum allowable gate opening (MAGO) criteria to keep discharge velocities from exceeding design limits and maximum permissible head (MPH) across the structure. These criteria are not explicitly considered by the daily timestep routing model. However, the S-61 capacity (S61Qcap) is computed daily using the simulated upstream and downstream stages and is limited by the user-input S61maxcap, currently set to 2,300 cfs.

The S-61 design discharge (2,300 cfs) also is the 98th percentile value of the historical flow data (1965 to 2005). The 99th percentile was 2,600 cfs. Maximum flow during the historical period was 3,750 cfs; however, this maximum is not recommended for S61maxcap because it is excessively high and inappropriate as an upper limit for simulating long-term performance. If flood peaks are of interest, more refinement to the model or a finer timestep hydraulic model may be needed.

Details about the daily S-61 hydraulic capacity computation (S61Qcap) are contained within the TOHops and TOHsim worksheets and are described below.

S61Qcap is the structure's hydraulic capacity, which is approximated by the UK-OPS Model as:

$$\mathrm{S61Qcap} = \mathrm{K}(HWEL - CEL)\sqrt{HWEL - TWEL} \tag{3.3.1}$$

Where:

HWEL = S61Hsim

TWEL = S65Hsim

CEL = 36.9 feet crest elevation

K = 190, derived from the following traditional orifice flow equation:

$$\mathrm{Q} = \mathrm{CA}\sqrt{2g(HWEL - TWEL)} \tag{3.3.2}$$

Where:

C = empirical discharge coefficient

A = L(HWEL-CEL)

g = gravity of Earth (32.2 ft/s^2)

L = gate width

By taking the ratio of Q/Q*, where Q* is the same equation using the design information, **Equation 3.3.1** can be derived. **Equation 3.3.1** is used by the UK-OPS Model for daily timestep approximation of the dynamic structure capacity. As described previously, S61Qcap cannot be larger than S61maxcap, which currently is set to the design capacity of 2,300 cfs.

3.3.2 Temporary Pump Capacity Assumptions for S-61

For testing scenarios such as TOH stage drawdown operations, which aim to periodically lower the lake stage below the elevation of the downstream KCH, the UK-OPS Model has a feature that allows specification of temporary pumps in parallel with the S-61 gated spillway. The TOHops worksheet allows specification of the average daily pump flow rate (S61pumpcap) and has an option to supplement gravity releases with pumping when the spillway capacity is less than the target release. Simultaneous gravity flow and pumping are simulated, and the user can specify a percent reduction in gravity capacity when pumping is used simultaneously. This accounts for the reduced spillway discharge rate due to the rise in tailwater stage from pumping (**Figure 3-4**).

3.3.3 Options for Simulating S-61 Operations

The UK-OPS Model has a few ways to simulate S-61 releases, which allows for testing alternative operations. **Table 3-2** shows the various settings of the parameter QoptTOH, which is specified in the TOHops worksheet.

Table 3-2. Optional UK-OPS Model operations for S-61 and Lake Tohopekaliga.

Parameter	Definition
QoptTOH = 0	Flow values set to inputs for testing routing calculations
QoptTOH = 1	Releases per operating zones and zone-discharge function
QoptTOH = 2	Same as Option 1, but gravity releases are supplemented with pumping when the spillway capacity is less than the target release (Qregadj).
QoptTOH = 3	Fixed, unrealistic 200 cubic feet per second release [placeholder for future option and code in routing worksheet (TOHsim)]
QoptTOH = 4	Releases per user-specified logic in routing worksheet (TOHsim) Currently set up to determine releases necessary to achieve user-specified stage recession rates within user-specified dates

3.4 Lakes Kissimmee, Cypress, and Hatchineha Regulation Schedule

The KCH regulation schedule specifies releases at S-65 depending primarily on lake stage. The KCH regulation schedule rules originally were designed to simply discharge water whenever the lake stage was above the schedule (**Figure 3-8**). However, during construction of the KRRP, an interim regulation schedule (**Figure 3-9**) and subsequent modifications to Zone B operations, were used. Interim operations were intended to be used until the Headwaters Revitalization regulation schedule is implemented upon completion of the KRRP (**Figure 3-10**). (It is important to note that new science and experience gained during the years of KRRP construction have yielded proposed refinements to the Headwaters Revitalization regulation schedule, particularly below Zone A.)

The KCH regulation schedule is more complex than the ETO and TOH schedules. The KCH schedule includes provisions that consider hydrologic conditions in the downstream Kissimmee River. Therefore, the options in the UK-OPS Model for simulating alternative operations of KCH are more complex than for ETO and TOH.

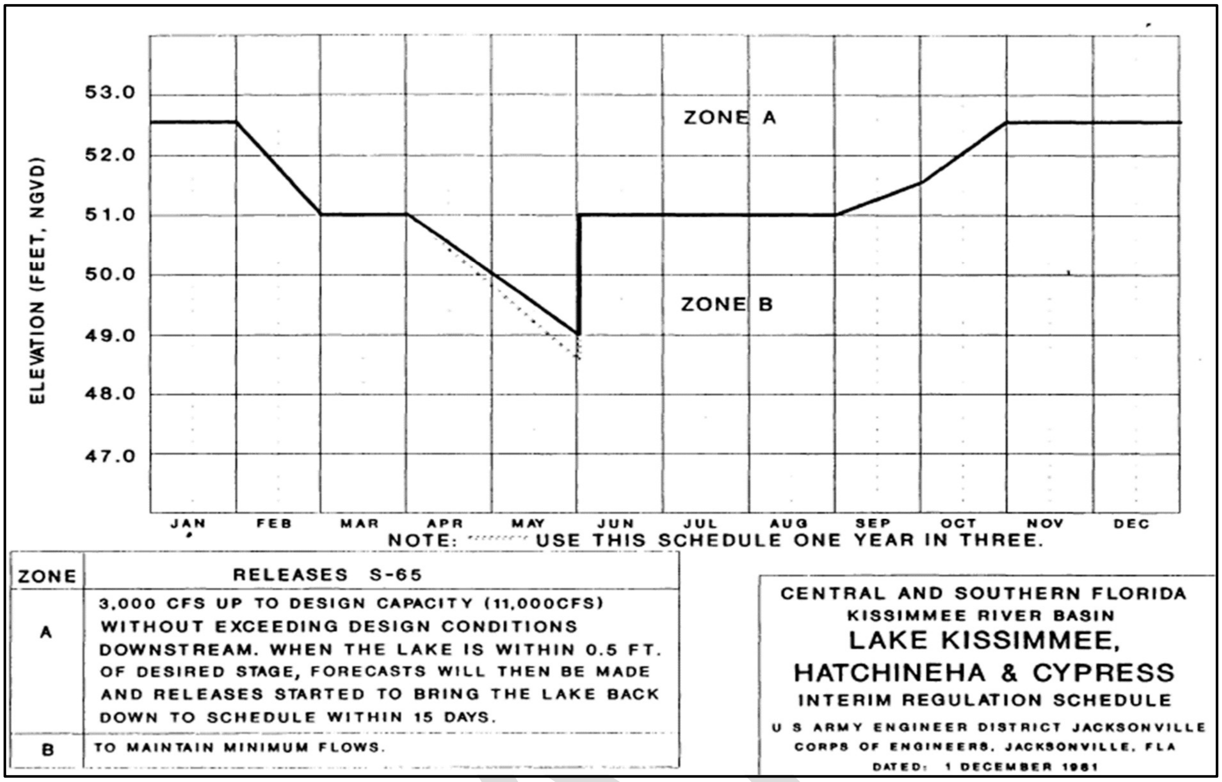


Figure 3-8. Pre-Kissimmee River Restoration Project regulation schedule for Lakes Kissimmee, Cypress, and Hatchineha.

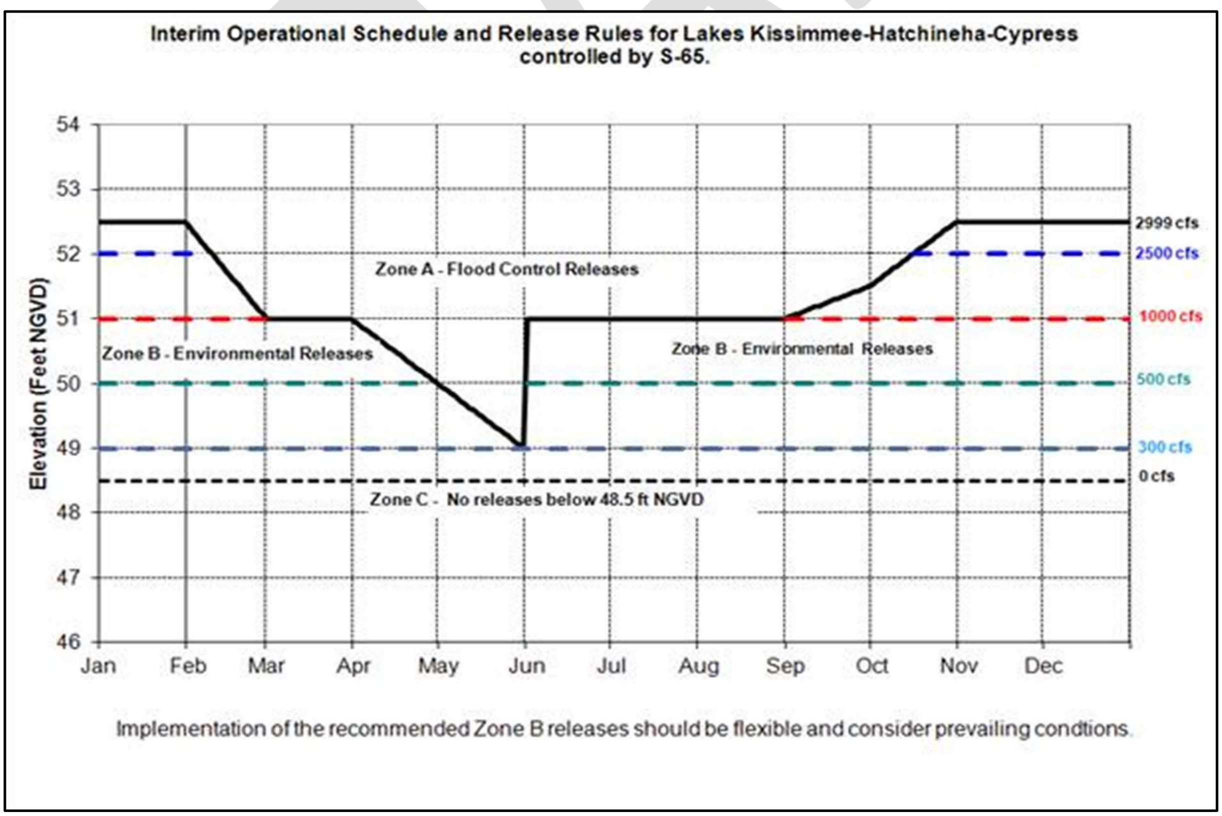


Figure 3-9. Lakes Kissimmee, Cypress, and Hatchineha interim regulation schedule.

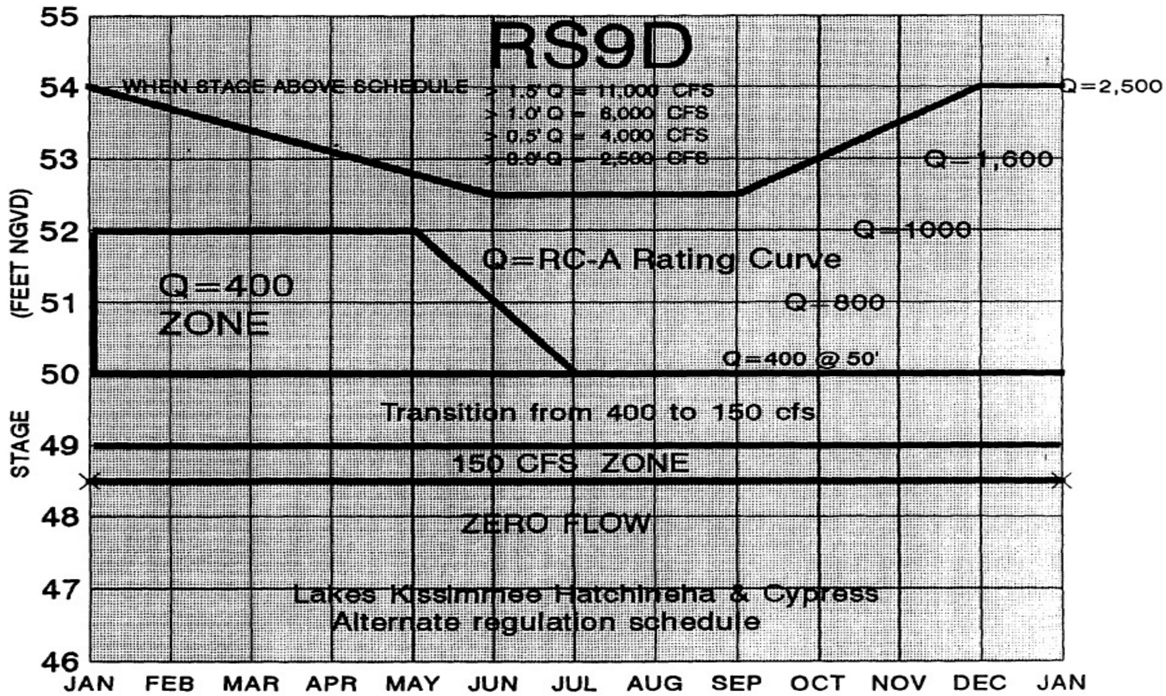
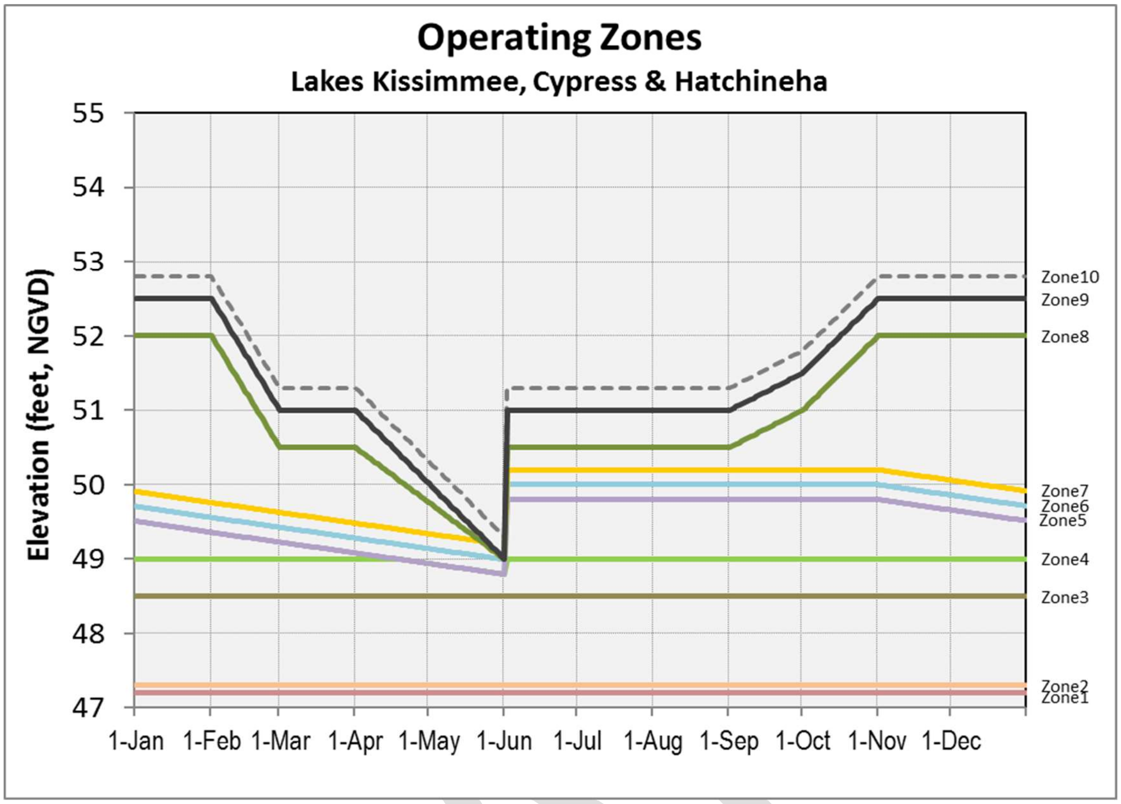


Figure 3-10. Lake Kissimmee, Cypress, and Hatchineha authorized Headwaters Revitalization regulation schedule. Recommended modified regulation schedule for the Kissimmee River Headwaters Revitalization Project (From: United States Army Corps of Engineers 1996).

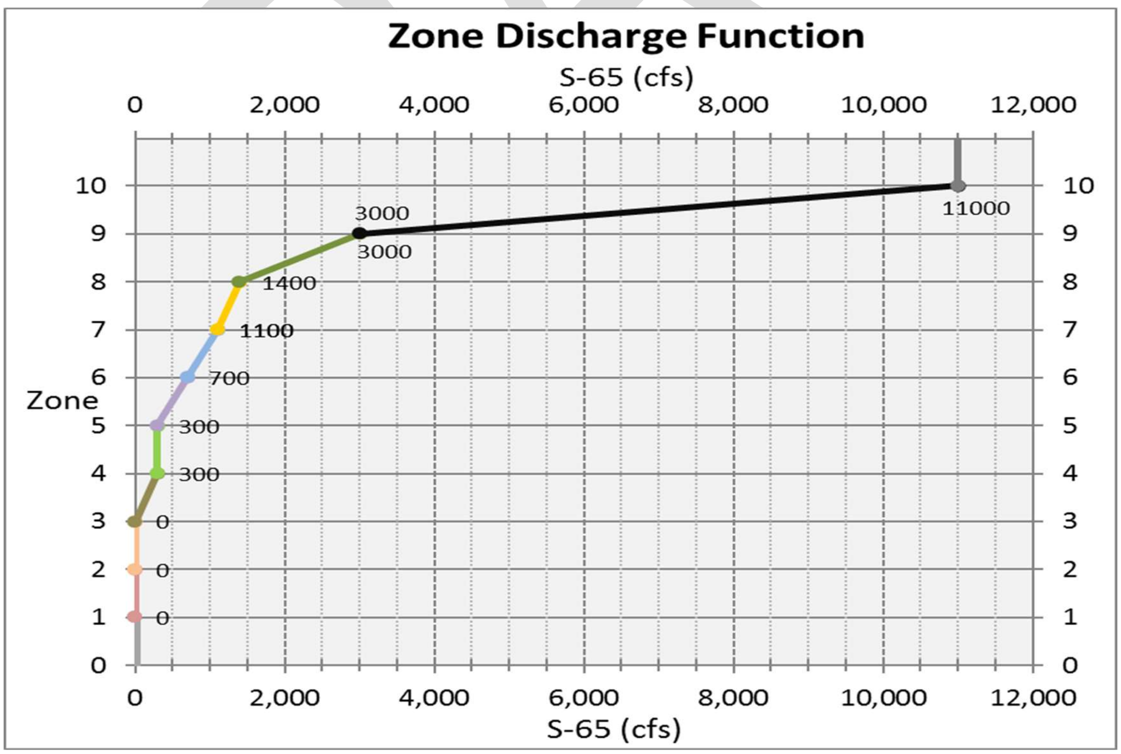
Figure 3-11 illustrates the KCH regulation schedule as seen by the UK-OPS Model. Up to 10 zones can be defined. The zones are numbered, and the labeled lines represent the bottom of the zone. The various zone lines in **Figure 3-11** represent the operation designed for the 2019 wet season to benefit fish and wildlife resources for KCH and the Kissimmee River. The dashed line (Zone 10) represents a 0.3-foot offset above the Zone A line (Zone 9) that is used to transition flows up to the maximum discharge. The model can simulate a linear transition from zero to maximum discharge in this range, if specified.

The UK-OPS Model uses a zone-discharge function to specify discharge rates within the regulation schedule zones. For KCH (**Figure 3-12**), the function is more complex than for ETO and TOH. As with the other zone-discharge functions, the zone number represents the bottom of the zone. Zero discharge is prescribed for all zones below Zone 3 (elevation 48.5 feet). Within Zone 3, discharge linearly increases with rising stage from 0 to 300 cfs. Zone 4 discharge is to be a constant 300 cfs, Zones 5 to 8 also specify linear variation with stage. Zone 9 transitions the discharge from 3,000 cfs at the top of the schedule (bottom of Zone A) to maximum capacity of 11,000 cfs at the Zone 10 dashed line, which is 0.3 feet above the schedule.

UK-OPS Model users can specify the breakpoints of the KCH regulation schedule and the zone-discharge function by changing the values in the color-coded tables within the KCHops worksheet. The regulation schedule and the zone-discharge function graphics automatically display changes to the inputs to enable verification of the intended changes.



3302
3303 Figure 3-11. Lakes Kissimmee, Cypress, and Hatchineha regulation schedule as seen by the UK-OPS
3304 Model.



3305
3306 Figure 3-12. Lakes Kissimmee, Cypress, and Hatchineha zone-discharge function used by the UK-OPS
3307 Model.

3.4.1 Hydraulic Capacity Assumptions for S-65 and S-65A

The S-65 five-gated spillway is capable of discharging up to 11,000 cfs. The downstream S-65A gated spillway also has a design capacity of 11,000 cfs. However, much of the capacity at S-65A is taken up by basin runoff; therefore, releases at S-65 generally are limited to avoid exceeding S-65A discharge capacity. Additionally, the operating criteria for S-65 provides for a firm capacity of 3,000 cfs. In other words, a minimum of 3,000 cfs must be released at S-65.

The UK-OPS Model uses a time series of basin runoff entering Pool A (the river reach from S-65 to S-65A) to determine the maximum release rates each day of the simulation. The model does not simulate the C-38 Canal stage within Pool A; therefore, even a rudimentary hydraulic discharge calculation, like that used for S-59 and S-61, is not possible. This has not proven to be a limitation of the UK-OPS Model period-of-record simulations because the discharges prescribed by the regulation schedule are almost always less than the 11,000 cfs limit at S-65A. Furthermore, when KCH Zone A releases are required, simulated runoff into the C-38 Canal within Pool A has not been high enough to trigger use of the firm capacity provision. A more detailed hydraulic model like the Mike 11 application for the Kissimmee River (SFWMD 2017) is needed to perform an analysis that involves assessing discharge capacity based on C-38 Canal stage.

4 MODEL STRUCTURE AND ORGANIZATION

4.1 Overview and User Interface

This section presents the structure and organization of the UK-OPS Model Excel® workbook, particularly the various worksheets and general data flow between worksheets. Descriptions of the primary inputs and computational worksheets are provided. The model output worksheets and performance graphics are described in **Section 5**.

Figure 4-1 illustrates the basic model structure and data flow between the worksheets. From the graphical user interface (GUI) worksheet (**Figure 2-3**), the user can specify simulation type, simulation name and description, and one of four output locations (ALT0 to ALT3). Simulations are executed from the GUI worksheet using the Run and Save buttons. The Retrieve button retrieves/loads previous scenario inputs into the worksheets that contain the active operating schedules for each lake system. Then, the inputs can be modified, and a new scenario can be executed. Macros execute the simulation and automatically manage the input and output data.

Clicking on the outlet structure name links on the GUI map transfers control to the corresponding operations worksheet where modifications to the regulation schedules and changes to other operating assumptions can be made (e.g., KCHops). The outlet structure discharge and routing calculations for each lake system are handled in separate worksheets named for each lake system (e.g., KCHsim).

Each lake system has a worksheet for specifying the input operations, and each simulation has a worksheet (ALT0 to ALT3) containing all the outputs as well as a copy of the input parameter values, which can be retrieved from the GUI buttons as noted above. Simulation outputs are automatically accessed by the time-series plots and performance summary graphics. In some cases, the summary graphics have dropdown menus to specify the particular simulation and summary information to display. A single 49-year, daily timestep, simulation executes in less than 4 minutes; thus, results are quickly available for analysis.

4.2 Operations Worksheets for Large Lake Systems

The following discussions focus on the operations-related input data sets used in the UK-OPS Model for the large lake systems. The KCHops, TOHops, and ETOops worksheets contain the operations input for lake systems KCH, TOH, and ETO, respectively. The information and organizational layout are similar among the three worksheets.

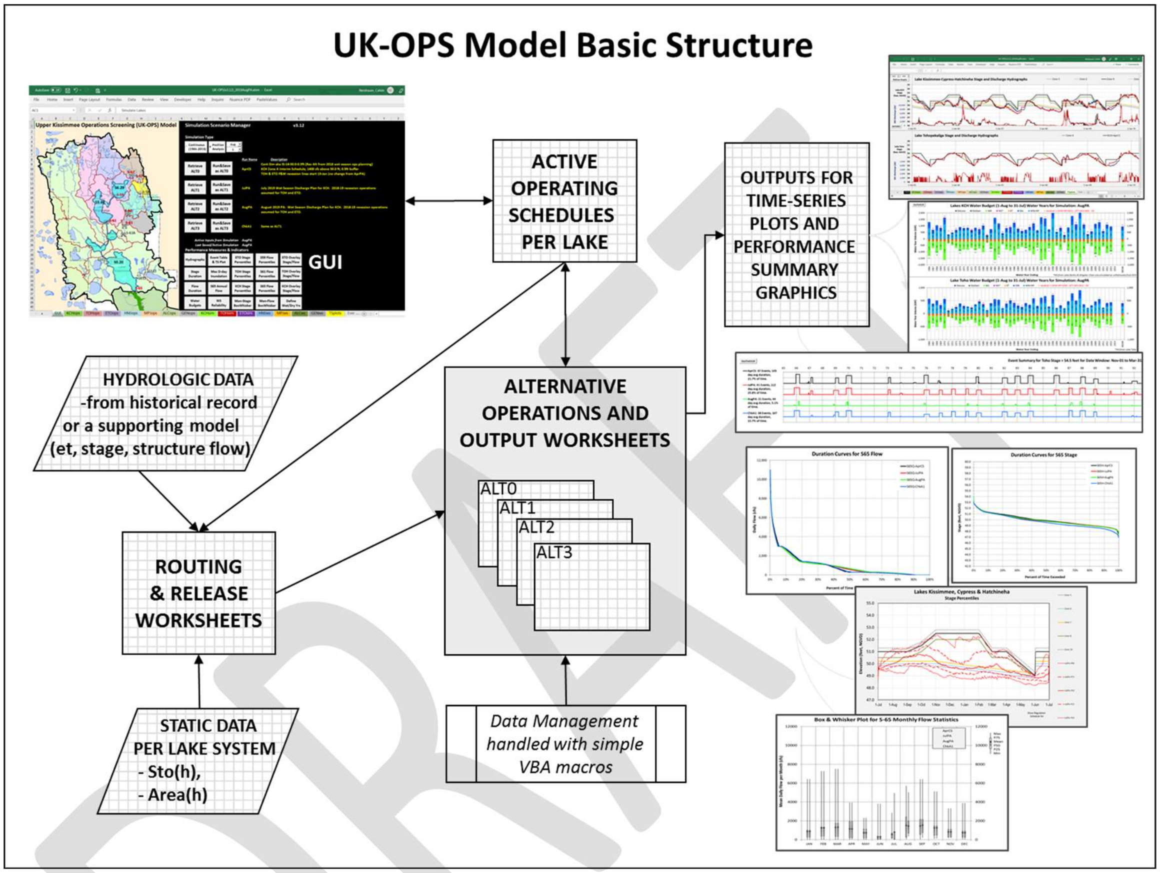


Figure 4-1. UK-OPS Model basic structure and data flow.

4.2.1 KCHops Worksheet

The KCHops worksheet contains operational information for the KCH system simulation. The model user can prescribe how to manage the KCH system by defining its regulation schedule, zone-discharge relationship, and parameters for releasing water to the Kissimmee River. In addition, various switches or flags for available operational features are defined in this worksheet.

The KCHops worksheet also contains copies of breakpoint data for past, present, and future planned KCH regulation schedules. These are located starting in column AP. The active schedule used for the simulation is in the predefined range OpZonesKCH, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints as needed to describe the desired schedule. The breakpoints are used to interpolate the daily values of each zone, which are displayed in the Operating Zones chart starting in column N. Similarly, the release rules and limits for describing the zone-discharge function, located under ReleaseRulesKCH, can be modified to reflect desired inputs. The entered breakpoints update the Zone-Discharge Function chart, which represents how the model will view the breakpoint information and serves as a helpful way to ensure the desired input is being used.

The UK-OPS Model has several ways to specify S-65 release rules. These features enable testing alternative operations to improve performance for the river and/or to improve the balance of performance between the river and KCH. The model also allows specification of an alternative regulation schedule to be used for user-specified conditions or for specifically defined years of the simulation. For example, this feature enables testing of periodic lake drawdown operations. Specifications for alternative operations begin in column AA.

Table 4-1 presents the various parameters and options available for testing alternative operations. Further details and tips are provided within the worksheet via mouse-over comments indicated by red triangles in the upper-right corner of pertinent cells.

Table 4-1. Optional UK-OPS Model operations for S-65 and Lakes Kissimmee, Cypress, and Hatchineha.

Parameter	Definition
QoptKCH = 0	Flow values set to inputs for testing routing calculations
QoptKCH = 1	Releases per operating zones and zone-discharge function
QoptKCH = 2	Option 1 with daily change in releases limited by maxDQrise and maxDQfall (**Figure 4-2**)
QoptKCH = 3	Option 2 but releases shift to zone-discharge function at zone boundaries
QoptKCH = 4	Zone B releases per user-specified flow time series Series number specified via parameter QoptS65tarQseries and points to series in the S65targetQseries worksheet
QoptKCH = 5	Releases per maximum of Options 1 and 4
QoptKCH = 6	Releases per user-specified logic in routing worksheet (KCHsim)
OptKCHalt = 1	Use alternative operations when user-specified stage conditions are met
OptKCHalt = 2	Use alternative operations for user-specified years

For QoptKCH values of 2 or 3 (**Table 4-1**), the release rate limits are specified by values shown in **Figure 4-2**. This figure represents a typical function specified to limit release rates at S-65 or S-65A depending on the previous day's discharge rate. Limits can be specified for increasing and decreasing discharge regimes.

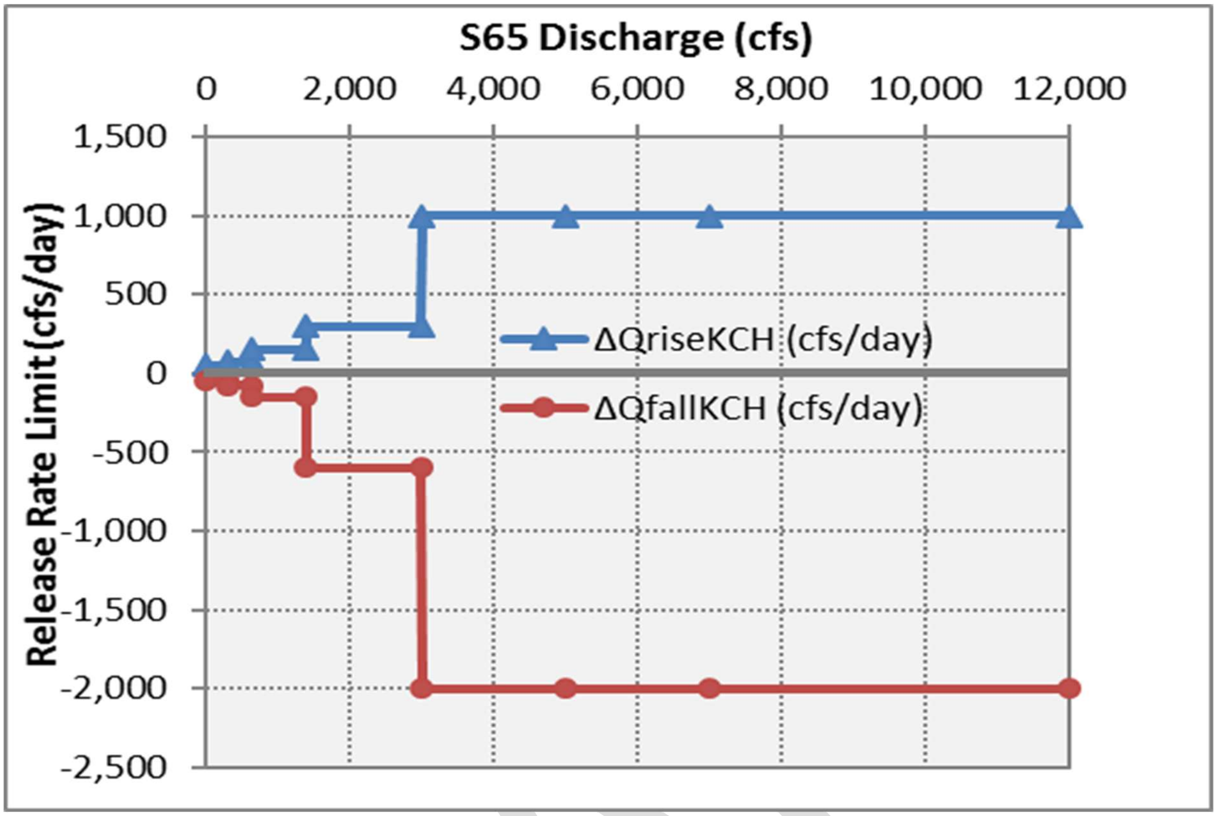


Figure 4-2. Example of S-65 release rate limits for Lakes Kissimmee, Cypress, and Hatchineha.

4.2.2 TOHops Worksheet

The TOHops worksheet contains operational information for the TOH system simulation. The model user can prescribe how to manage TOH by defining its regulation schedule, zone-discharge relationship, and other parameters. In addition, various switches or flags for available operational features are defined in this worksheet.

The TOHops worksheet contains breakpoint data for several alternative regulation schedules that have been tested or actually used for TOH. These are located starting in column AA. The active schedule used for the simulation is in the predefined range OpZonesTOH, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints as needed to describe the desired schedule. The breakpoints are used to interpolate the daily values of each zone and are displayed in the Operating Zones chart starting in column J. Similarly, the release rules and limits for describing the zone-discharge function, located in ReleaseRulesTOH, can be modified to reflect desired inputs. The breakpoints entered update the Zone-Discharge Function chart, which represents how the model will view the breakpoint information and serves as a helpful way to ensure the desired input is being used.

Other inputs in the TOHops worksheet include water supply withdrawal parameters, which enable testing user-specified withdrawals subject to the draft KRCOL Water Reservation rules. Switches are available that require up to three conditions to be satisfied before the simulated withdrawal is made.

Table 4-2 presents the various parameters and options available for testing alternative operations. Further details and tips are provided within the worksheet via mouse-over comments indicated by red triangles in the upper-right corner of pertinent cells.

Table 4-2. Optional UK-OPS Model operations for S-61 and Lake Tohopekaliga.

Parameter	Definition
QoptTOH = 0	Flow values set to inputs for testing routing calculations
QoptTOH = 1	Releases per operating zones and zone-discharge function
QoptTOH = 2	Same as Option 1, but gravity releases are supplemented with pumping when the spillway capacity is less than the target release
QoptTOH = 3	Constant 200 cubic feet per second release (placeholder for future option and code)
QoptTOH = 4	Releases per user-specified logic in routing worksheet (TOHsim)

4.2.3 ETOops Worksheet

The ETOops worksheet contains operational information for the ETO system simulation. The model user can prescribe how to manage ETO by defining its regulation schedule, zone-discharge relationship, and other parameters. In addition, various switches or flags for available operational features are defined in this worksheet.

The ETOops worksheet contains breakpoint data for several alternative regulation schedules that have been tested or actually used for ETO. These are located starting in column AA. The active schedule used for the simulation is in the predefined range OpZonesETO, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints as needed to describe the desired schedule. The breakpoints are used to interpolate the daily values of each zone and are displayed in the Operating Zones chart starting in column J. Similarly, the release rules and limits for describing the zone-discharge function, located in ReleaseRulesETO, can be modified to reflect desired inputs. The entered breakpoints update the Zone-Discharge Function chart, which represents how the model will view the breakpoint information and serves as a helpful way to ensure the desired input is being used.

Other inputs in the ETOops worksheet include water supply withdrawal parameters, which enable testing user-specified withdrawals subject to the draft KRCOL Water Reservation rules. Switches are available that require up to three conditions to be satisfied before the simulated withdrawal is made.

Table 4-3 presents the various parameters and options available for testing alternative operations. Further details and tips are provided within the worksheet via mouse-over comments indicated by red triangles in the upper-right corner of pertinent cells.

Table 4-3. Optional UK-OPS Model operations for S-59 and East Lake Tohopekaliga.

Parameter	Definition
QoptETO = 0	Flow values set to inputs for testing routing calculations
QoptETO = 1	Releases per operating zones and zone-discharge function
QoptETO = 2	Same as Option 1, but gravity releases are supplemented with pumping when the spillway capacity is less than the target release
QoptETO = 3	Constant 200 cubic feet per second release (placeholder for future option and code)
QoptETO = 4	Releases per user-specified logic in routing worksheet (ETOsim)

4.3 Operations Worksheets for Small Lake Systems

This section describes the operations-related input data sets used in the UK-OPS Model for the small lake systems. The HMJops, MPJops, ALCops, and GENops worksheets contain the operations input for lake systems HMJ, MPJ, ALC, and GEN, respectively. The information and organizational layout are similar among the four worksheets. There is no routing of inflows and outflows through the small lake systems in the current configuration of the UK-OPS Model. Boundary inflows are defined in the WNI calculation, as described in **Sections 2.2** to **2.5**. The small lakes are included only to test water supply withdrawal scenarios subject to the draft KRCOL Water Reservation rules. As described in **Section 2.5**, withdrawals from the small lakes are simulated as withdrawals from the next downstream large lake system.

4.3.1 HMJops Worksheet

The HMJops worksheet contains operational information for simulating the HMJ system. The modeled operational information is limited to specification of the WRL. Various switches or flags for available KRCOL Water Reservation criteria also are defined in this worksheet.

The HMJ regulation schedule is in the predefined range OpZonesHMJ, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints of the schedule, but it has no bearing on the simulation; only changes to the WRL can affect the simulation. The WRL, along with other draft KRCOL Water Reservation rule criteria, determine when water supply withdrawals can occur.

The UK-OPS Model has five optional conditions in the HMJops worksheet that can be evaluated to determine if water supply withdrawals can occur:

1. HMJ stage above its WRL?
2. ETO stage above its WRL?
3. TOH stage above its WRL?
4. KCH stage above its WRL?
5. Lake Okeechobee discharging excess water to tide?

Typically, conditions 1 and 2 or conditions 1, 2, and 5 are set to TRUE to determine when the prescribed HMJ withdrawal capacity can be taken. Withdrawals can occur if the HMJ and ETO stages are above their respective WRLs and the other draft KRCOL Water Reservation rule criteria are met. Recognizing the withdrawal may reduce lake outflow and affect the downstream large lake system, the UK-OPS Model assumes the withdrawal is directly from the downstream large lake system, ETO in this instance.

4.3.2 MPJops Worksheet

The MPJops worksheet contains operational information for simulating the MPJ system. The modeled operational information is limited to specification of the WRL. Various switches or flags for available KRCOL Water Reservation criteria also are defined in this worksheet.

The MPJ regulation schedule is in the predefined range OpZonesMPJ, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints of the schedule, but it has no bearing on the simulation; only changes to the WRL can affect the simulation. The WRL, along with other proposed KRCOL Water Reservation criteria, determines when water supply withdrawals can occur.

The UK-OPS Model has six optional conditions in the MPJops worksheet that can be evaluated to determine if water supply withdrawals can occur:

1. MPJ stage above its WRL?
2. HMJ stage above its WRL?
3. ETO stage above its WRL?
4. TOH stage above its WRL?
5. KCH stage above its WRL?
6. Lake Okeechobee discharging excess water to tide?

Typically, conditions 1, 2, and 3 or conditions 1, 2, 3, and 5 are set to TRUE to determine when the prescribed MPJ withdrawal capacity can be taken. Withdrawals can occur if the MPJ, HMJ, and ETO stages are above their respective WRLs and the other draft KRCOL Water Reservation rule criteria are met. Recognizing the withdrawal may reduce lake outflow and affect the downstream large lake system, the UK-OPS Model assumes the withdrawal is directly from the downstream large lake system, ETO in this instance.

4.3.3 ALCops Worksheet

The ALCops worksheet contains operational information for simulating the ALC system. The modeled operational information is limited to specification of the WRL. Various switches or flags for available KRCOL Water Reservation criteria also are defined in this worksheet.

The ALC regulation schedule is in the predefined range OpZonesALC, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints of the schedule, but it has no bearing on the simulation; only changes to the WRL can affect the simulation. The WRL, along with other draft KRCOL Water Reservation criteria, determines when water supply withdrawals can occur.

The UK-OPS Model has four optional conditions in the ALCops worksheet that can be evaluated to determine if water supply withdrawals can occur:

1. ALC stage above its WRL?
2. GEN stage above its WRL?
3. KCH stage above its WRL?
4. Lake Okeechobee discharging excess water to tide?

Typically, conditions 1, 2, and 3 or all four conditions are set to TRUE to determine when the prescribed ALC withdrawal capacity can be taken. Withdrawals can occur if the ALC, GEN, and KCH stages are above their respective WRLs and the other draft KRCOL Water Reservation rule criteria are met. Recognizing the withdrawal may reduce lake outflow and affect the downstream large lake system, the UK-OPS Model assumes the withdrawal is directly from the downstream large lake system, KCH in this instance.

4.3.4 GENops Worksheet

The GENops worksheet contains operational information for simulating the GEN system. The modeled operational information is limited to specification of the WRL. Various switches or flags for available KRCOL Water Reservation criteria also are defined in this worksheet.

The GEN regulation schedule is in the predefined range OpZonesGEN, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints of the schedule, but it has no bearing on the simulation; only changes to the WRL can affect the simulation. The WRL, along with other draft KRCOL Water Reservation criteria, determines when water supply withdrawals can occur.

The UK-OPS Model has three optional conditions in the GENops worksheet that can be evaluated to determine if water supply withdrawals can occur:

1. GEN stage above its WRL?
2. KCH stage above its WRL?
3. Lake Okeechobee discharging excess water to tide?

Typically, conditions 1 and 2 or all three conditions are set to TRUE to determine when the prescribed GEN withdrawal capacity can be taken. Withdrawals can occur if the GEN and KCH stages are above their respective WRLs and the other draft KRCOL Water Reservation rule criteria are met. Recognizing the withdrawal may reduce lake outflow and affect the downstream large lake system, the UK-OPS Model assumes the withdrawal is directly from the downstream large lake system, KCH in this instance.

4.4 Routing Worksheets for Large Lake Systems

This section describes the routing worksheets for the three large lake systems simulated by the UK-OPS Model. Most simulation calculations occur in the routing sheets using traditional Microsoft Excel® formulas. Routing calculations are not handled by Visual Basic for Applications (VBA) program code via Microsoft Excel® macros. Macros are used by the model but primarily to manage the data. The ETOsim, TOHsim, and KCHsim worksheets contain calculations for determining releases and stages for lake systems ETO, TOH, and KCH, respectively. The information and organizational layout are similar among the three routing worksheets. To best understand the worksheets, readers should have the UK-OPS Model workbook open to follow along with the descriptions.

4.4.1 ETOsim Worksheet

The ETOsim worksheet performs the primary simulation for the ETO system. The worksheet contains: 1) the daily timestep computations for processing boundary conditions, namely WNI+RF; 2) calculations of lake outflows and stages using user-prescribed operating rules; and 3) processing of several metrics of performance, which are used to automatically update the output performance measures and charts (refer to **Section 5**).

4.4.1.1 Boundary Conditions

Calculations for computing the WNI+RF boundary series are contained in columns B through K of the ETOsim worksheet. **Equation 2.2.2** was derived for WNI+RF (**Section 2.2**) and is computed in column K. Because WNI+RF is a persistent time series, it only needs to be calculated once. The shaded cells in the worksheet have formulas, whereas the unshaded cells (starting in row 18) contain only values. If input hydrology data values change, then the ETO_ResetInputData macro (button near cell E4) must be executed to recalculate the WNI+RF values.

4.4.1.2 Routing

Simulation calculations for ETO stages and S-59 discharges begin in column L of the ETOsim worksheet. The fundamental routing equation (**Equation 2.2.1**) used was presented in **Section 2.2**. The calculation uses the beginning-of-day stage, storage, and area for calculating ET volume (column T) and structure discharge (column AK). Water supply withdrawals, if any, are totaled in column AT. Storage change, end-of-day storage, and stage are computed in columns AU through AX. The end-of-day values become the beginning-of-day values for the next day. Calculations proceed for each day of the simulation.

When the simulation is executed, the ETO_Expand_Formulas macro expands the routing formulas starting January 7, 1965 (row 17) for all the simulation days. Then the execution runs the ETO_Formulas2Values macro to save the computed formulas as values for further processing. This procedure saves workbook space and computational resources. Buttons at the top of column T are available to execute the macros (e.g., if needed for testing), independent of the simulation execution.

4.4.1.3 Summary Statistics

After routing is completed, the UK-OPS Model processes the simulation output in many different forms. Daily stage and flow tables are automatically updated via the RunSaveETOStgStats and RunSaveS59FlowStats macros, respectively. The stage tables are within worksheet range BD7 through DK393, and the flow tables are within worksheet range BD407 through BK793. Water budget calculations are within workbook range DO8 through EF62. Water supply reliability calculations are within workbook range EI8 through EY17907.

4.4.2 TOHsim Worksheet

The TOHsim worksheet performs the primary simulation for the TOH system. The worksheet contains: 1) the daily timestep computations for processing boundary conditions, namely WNI+RF; 2) calculations of lake outflows and stages using user-prescribed operating rules; and 3) processing of several metrics of performance, which are used to automatically update the output performance measures and charts (refer to **Section 5**).

4.4.2.1 Boundary Conditions

Calculations for computing the WNI+RF boundary series are contained in columns B through K of the TOHsim worksheet. **Equation 2.3.2** was derived for WNI+RF (**Section 2.3**) and is computed in column K. Because WNI+RF is a persistent time series, it only needs to be calculated once. The shaded cells in the worksheet have formulas, whereas the unshaded cells (starting in row 18) contain only values. If input hydrology data values change, then the TOH_ResetInputData macro (button near cell E4) must be executed to recalculate the WNI+RF values.

4.4.2.2 Routing

Simulation calculations for TOH stages and S-61 discharges begin in column L of the TOHsim worksheet. The fundamental routing equation (**Equation 2.3.1**) was presented in **Section 2.3**. The calculation uses the beginning-of-day stage, storage, and area for calculating ET volume (column T) and structure discharge (column AK). Water supply withdrawals, if any, are evaluated in column AP. Storage change, end-of-day storage, and stage are computed in columns AQ through AT. The end-of-day values become the beginning-of-day values for the next day. Calculations proceed for each day of the simulation.

When the simulation is executed, the TOH_Expand_Formulas macro expands the routing formulas starting January 7, 1965 (row 17) for all the simulation days. Then the execution runs the TOH_Formulas2Values macro to save the computed formulas as values for further processing. This procedure saves workbook space and computational resources. Buttons located at the top of column T are available to execute the macros (e.g., if needed for testing), independent of the simulation execution.

4.4.2.3 Summary Statistics

After routing is completed, the UK-OPS Model processes the simulation output in many different forms. Daily stage and flow tables are automatically updated via the RunSaveTOHStgStats and RunSaveS61FlowStats macros, respectively. The stage tables are within worksheet range BD7 through DK393, and the flow tables are within worksheet range BD407 through BK793. Water budget calculations are within workbook range DO8 through EF62. Water supply reliability calculations are within workbook range EI8 through EY17907.

4.4.3 KCHsim Worksheet

The KCHsim worksheet performs the primary simulation for the KCH system. The worksheet contains: 1) the daily timestep computations for processing boundary conditions, namely WNI+RF; 2) calculations of lake outflows and stages using user-prescribed operating rules; and 3) processing of several metrics of performance, which are used to automatically update the output performance measures and charts (refer to **Section 5**).

4.4.3.1 Boundary Conditions

Calculations for computing the WNI+RF boundary series are contained in columns B through K of the KCHsim worksheet. **Equation 2.4.2** was derived for WNI+RF (**Section 2.4**) and is computed in column K. Because WNI+RF is a persistent time series, it only needs to be calculated once. The shaded cells in the worksheet have formulas, whereas the unshaded cells (starting in row 18) contain only values. If input hydrology data values change, then the KCH_ResetInputData macro (button near cell E4) must be executed to recalculate the WNI+RF values.

4.4.3.2 Routing

Simulation calculations for KCH stages as well as S-65 and S-65A discharges begin in column M of the KCHsim worksheet. The fundamental routing equation (**Equation 2.4.1**) was presented in **Section 2.4**. The calculation uses the beginning-of-day stage, storage, and area for calculating ET volume (column T) and structure discharge (columns AU and AV). Water supply withdrawals, if any, are totaled in column AY. Storage change, end-of-day storage, and stage are computed in columns AZ through BC. The end-of-day values become the beginning-of-day values for the next day. Calculations proceed for each day of the simulation.

When the simulation is executed, the KCH_Expand_Formulas macro expands the routing formulas starting January 7, 1965 (row 17) for all the simulation days. Then the execution runs the KCH_Formulas2Values macro to save the computed formulas as values for further processing. This procedure saves workbook space and computational resources. Buttons located at the top of column T are available to execute the macros (e.g., if needed for testing), independent of the simulation execution.

4.4.3.3 Summary Statistics

After routing is completed, the UK-OPS Model processes the simulation output in many different forms. Daily stage tables are automatically updated via the RunSaveKCHStgStats macro, and daily flow tables for S-65 and S-65A are automatically updated via the RunSaveS65FlowStats and RunSaveS65AFlowStats macros, respectively. The stage tables are within worksheet range BG7 through DN393, and the flow tables for S-65 and S-65A are within worksheet ranges BG407 through DN793 and BG807 through DN1193, respectively. Water budget calculations are within workbook range DR8 through EI62. There are no water supply reliability calculations in the UK-OPS Model for the KCH system because the draft KRCOL Water Reservation rules do not permit withdrawals from this lake system.

4.5 Water Supply Worksheets for Small Lake Systems

This section describes the water supply worksheets for the four small lake systems simulated by the UK-OPS Model. As previously mentioned, routing currently is not simulated for the small lake systems in the UK-OPS Model. The small lake systems are used only to determine the timing and volume of potential water supply withdrawals subject to the proposed KRCOL Water Reservation rule constraints. The HMJws, MPJws, ALCws, and GENws worksheets contain calculations for simulating water supply withdrawals from lake systems HMJ, MPJ, ALC, and GEN, respectively. The information and organizational layout are similar among the four worksheets. To best understand the worksheets, readers should have the UK-OPS Model workbook open to follow along with the descriptions.

4.5.1 HMJws Worksheet

The HMJws worksheet determines if user-prescribed water supply withdrawals can be made from the HMJ lake system. The worksheet is much simpler and smaller than the routing worksheets for the large lake systems. The HMJws worksheet: 1) contains the daily timestep computations that compare the HMJ input stages and stages in the downstream lakes with their respective WRLs; and 2) processes the number of days per month that water supply withdrawals were simulated.

Withdrawals allowed from the HMJ system are simulated as withdrawals from the next downstream large lake system, ETO in this instance. The assumption is that withdrawals from HMJ would reduce inflows to ETO, thus the model makes the withdrawal, subject to constraints, from ETO.

To save computation resources, this worksheet expands the formulas for the simulation period to make the necessary computations, then saves the formulas as values. The HMJ_Expand_Formulas and HMJ_Formulas2Values macros are executed automatically during a simulation. Buttons in column R can run the macros independent of the simulation for testing.

4.5.2 MJPws Worksheet

The MPJws worksheet determines if user-prescribed water supply withdrawals can be made from the MPJ lake system. The worksheet is much simpler and smaller than the routing worksheets for the large lake systems. The MPJws worksheet: 1) contains the daily timestep computations that compare the MPJ input stages and stages in the downstream lakes with their respective WRLs; and 2) processes the number of days per month that water supply withdrawals were simulated.

Withdrawals allowed from the MPJ system are simulated as withdrawals from the next downstream large lake system, ETO in this instance. The assumption is that withdrawals from MPJ would reduce inflows to ETO, thus the model makes the withdrawal, subject to constraints, from ETO.

To save computation resources, this worksheet expands the formulas for the simulation period to make the necessary computations, then saves the formulas as values. The MPJ_Expand_Formulas and MPJ_Formulas2Values macros are executed automatically during a simulation. Buttons in column R can run the macros independent of the simulation for testing.

4.5.3 ALCws Worksheet

The ALCws worksheet determines if user-prescribed water supply withdrawals can be made from the ALC lake system. The worksheet is much simpler and smaller than the routing worksheets for the large lake systems. The ALCws worksheet: 1) contains the daily timestep computations that compare the ALC input stages and stages in the downstream lakes with their respective WRLs; and 2) processes the number of days per month that water supply withdrawals were simulated.

Withdrawals allowed from the ALC system are simulated as withdrawals from the next downstream large lake system, KCH in this instance. The assumption is that withdrawals from ALC would reduce inflows to KCH, thus the model makes the withdrawal, subject to constraints, from KCH.

To save computation resources, this worksheet expands the formulas for the simulation period to make the necessary computations, then saves the formulas as values. The ALC_Expand_Formulas and ALC_Formulas2Values macros are executed automatically during a simulation. Buttons in column R can run the macros independent of the simulation for testing.

4.5.4 GENws Worksheet

The GENws worksheet determines if user-prescribed water supply withdrawals can be made from the GEN lake system. The worksheet is much simpler and smaller than the routing worksheets for the large lake systems. The GENws worksheet: 1) contains the daily timestep computations that compare the GEN input stages and stages in the downstream lakes with their respective WRLs; and 2) processes the number of days per month that water supply withdrawals were simulated.

Withdrawals allowed from the GEN system are simulated as withdrawals from the next downstream large lake system, KCH in this instance. The assumption is that withdrawals from GEN would reduce inflows to KCH, thus the model makes the withdrawal, subject to constraints, from KCH.

To save computation resources, this worksheet expands the formulas for the simulation period to make the necessary computations, then saves the formulas as values. The GEN_Expand_Formulas and GEN_Formulas2Values macros are executed automatically during a simulation. Buttons in column R can run the macros independent of the simulation for testing.

4.6 Other Input Worksheets

The remaining input worksheets for the UK-OPS Model are described in this section. The following input worksheets contain the various time-series input data generated by the more detailed hydrologic models: DATAforUKOPS, UKISSforUKOPS, and AFETforUKOPS. As mentioned in **Section 1**, the UK-OPS Model does not simulate the rainfall-runoff hydrologic process. Instead, it computes watershed inflows to each lake using key hydrologic information from detailed hydrologic models or the historical record.

Other UK-OPS Model input worksheets include S65TargetQseries, which provides flow targets for optional use with KCH operations, and StageStoArea, which contains the static data representing the geometric, or stage-area and stage-storage, relationships used for the routing computations.

4.6.1 DATAforUKOPS Worksheet

The DATAforUKOPS worksheet contains historical lake stage and structure flow data for optional use in computing the boundary condition inflows (WNI+RF), as defined in **Section 2** and calculated in the routing worksheets (**Section 4.4**).

The DATAforUKOPS worksheet is a product of two separate Microsoft Excel® workbooks used to assemble various stage and discharge data sets and to estimate missing values: DataPrepForUKOPSmodel.xlsx and StructureQHWTW_DBHydro_AFET-LT(CN18Aug2015).xlsx. Using the historical data in this worksheet as the basis for the boundary conditions has the advantage of not relying on a particular model for the rainfall-runoff simulation. To evaluate the effects of proposed water withdrawals on the draft KRCOL Water Reservation rules, historical data for a specific 41-year period (1965 to 2005) are specified. This establishes a fixed data set and period that will not change over time.

4.6.2 UKISSforUKOPS Worksheet

The UKISSforUKOPS worksheet contains simulated lake stage and structure flow data for optional use in computing the boundary condition inflows (WNI+RF), as defined in **Section 2** and calculated in the routing worksheets (**Section 4.4**). The UKISSforUKOPS worksheet contains the output from the Upper Kissimmee Chain of Lakes Routing Model (UKISS) (Fan 1986). Specific UKISS output files are referenced in the worksheet. Using these data to compute the boundary conditions implicitly uses the rainfall-runoff methods and other assumptions of UKISS. UKISS was the only regional hydrologic and water management model for the basin in the 1980s and 1990s. Several models have been developed in the past 20 years that have replaced UKISS, the most recent being the Regional Simulation Model – Basins Model (VanZee 2011).

4.6.3 AFETforUKOPS Worksheet

The AFETforUKOPS worksheet contains simulated lake stage and structure flow data for optional use in computing the boundary condition inflows (WNI+RF), as defined in **Section 2** and calculated in the routing worksheets (**Section 4.4**). The AFETforUKOPS worksheet contains output from the Alternative Formulation and Evaluation Tool (AFET), an application of the Mike 11/Mike SHE Model to the Kissimmee Basin (SFWMD 2009, 2017). Specific AFET output files are referenced in the worksheet. Using these data to compute the boundary conditions implicitly uses the rainfall-runoff methods and other assumptions of AFET and Mike 11/Mike SHE. AFET was developed by the SFWMD with assistance from the Architectural and Engineering Company (AECOM) and the Danish Hydraulic Institute (DHI) in support of the Kissimmee Basin Modeling and Operations Study (KBMOS), which ended prematurely in 2013. The modeling tools were further refined by the SFWMD in 2016 to 2018.

4.6.4 S65TargetQSeries Worksheet

The UK-OPS Model has an option to use a target flow time series at S-65 or S-65A for environmental flows to the Kissimmee River. This concept is similar to the Everglades' Shark River Slough Rainfall Plan and the Tamiami Trail Flow Formula for delivering target environmental flows. Up to 11 series can be input in the S65TargetQSeries worksheet. Currently, this worksheet contains only one input series, RDTSv5r, which mimics the pre-channelization rainfall-runoff response of the UKB. Development of this series is a separate topic.

4.6.5 StageStoArea Worksheet

The StageStoArea worksheet contains stage-storage and stage-area information for the three large lake systems: KCH, TOH, and ETO. The data used for these relationships (**Figure 4-3**) came from the development work done by Ken Konyha of the SFWMD when AFET was being developed in 2007. The stage-storage relationship is used with the daily routing to relate storage to stage. The stage-area relationship is used to compute lake surface areas to calculate corresponding ET volumes.

Although small lakes are not included in the StageStoArea worksheet (or in **Figure 4-3**), it should be noted that the large lakes represent 86% of the total storage capacity and total surface area of all managed lakes in the UKB at winter pool stages.

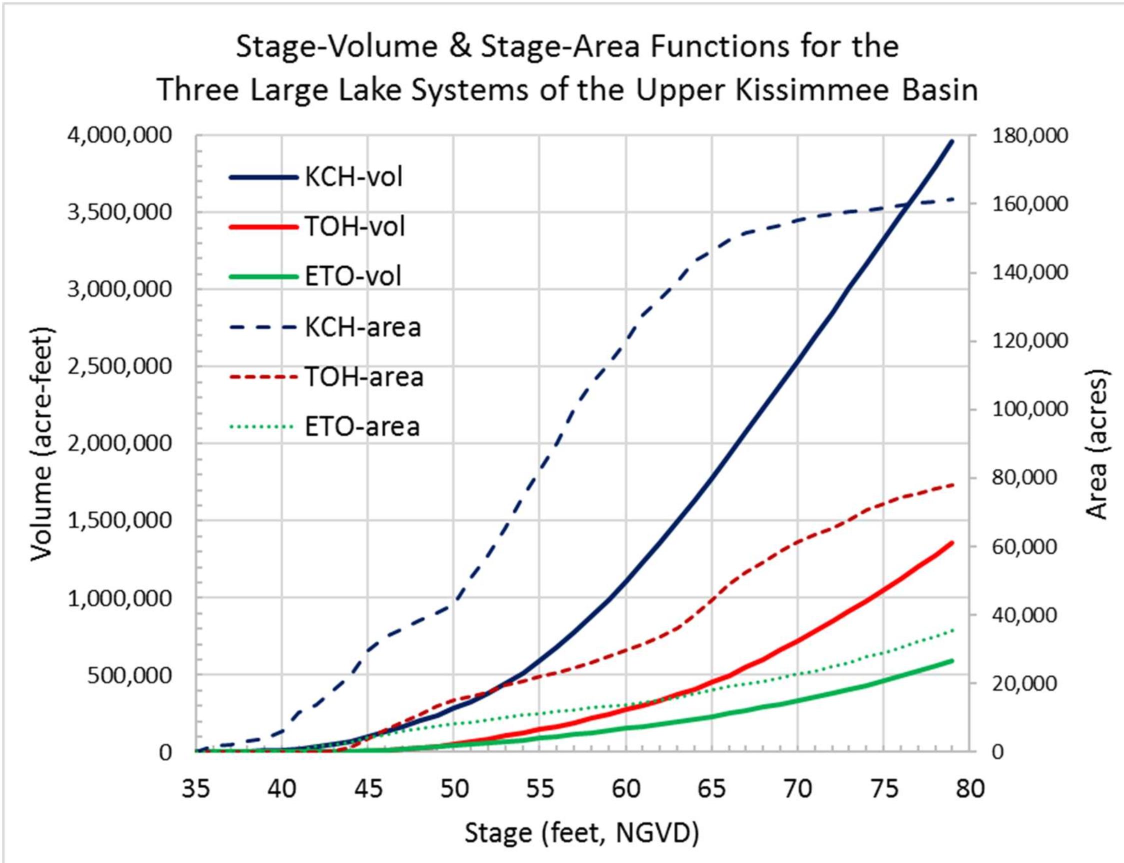


Figure 4-3. Stage-volume and stage-area relationships used by the UK-OPS Model.

5 MODEL OUTPUT

The UK-OPS Model outputs daily time series of stages and releases from the UKB's three largest lake systems into the user-specified ALT0, ALT1, ALT2, and ALT3 worksheets. The model also automatically generates graphical and tabular summaries of simulated performance for evaluating current or proposed operations and/or water supply withdrawal scenarios. These summaries access the pertinent outputs from the ALT worksheets and can be accessed via the buttons on the lower-right portion of the GUI (**Figure 2-3**). This section describes the specific outputs available in the current version of the model.

5.1 Measures of Performance

Simulation model outputs can be summarized in many ways. Traditional outputs include hydrographs (time-series plots of stage and/or flow), water budgets, and various statistical summaries of stage and flow critical to analysts and/or stakeholders. The term "performance measure" has a specific definition for hydrologic simulation modeling analysis in Central and South Florida. Performance measures are quantitative indicators of how well (or poorly) a simulation scenario meets a specific objective. They are a means to make relative comparisons among different test scenarios. Characteristics of a good performance measure are that it

- is quantifiable,
- has a specific target,
- indicates when that target has been reached, and/or
- measures the degree of improvement towards the target when the target has not been reached.

Performance measures are a special class of model outputs that enable a more conclusive interpretation of the simulations. Most UK-OPS Model outputs do not meet this definition of a performance measure. Rather, the UK-OPS Model outputs are better classified as performance indicators, or more generically, measures of performance. These do not have specific targets but are useful for making relative comparisons among alternative scenarios.

The UK-OPS Model output summary measures are hydrologic in nature, and many are considered ecological surrogates (e.g., S-65 annual average flow has a specific limit tied to the ecological health of the Kissimmee River). The UK-OPS Model automatically generates more than 20 output summary measures, classified into two groups: 1) daily stage and flow displays, and 2) hydrologic performance summaries.

5.2 Daily Stage and Flow Displays

The fundamental outputs from a hydrologic simulation model are flows and stages, commonly displayed using hydrographs. Typically, stage and flow series also are displayed as duration curves and percentile plots, which indicate the data distribution. These displays are produced by the UK-OPS Model and are described below.

5.2.1 Hydrographs

The TSplots worksheet can be accessed using the Hydrographs button. The worksheet contains stage and outflow hydrographs for the UKB's three large lake systems and have been very useful for detailed analyses. **Figure 5-1** is an example worksheet showing KCH and TOH. The plots have options to turn on/off particular simulations and regulation schedules. The slider bar enables viewing the entire plot, which also can be scaled to a specified time window. The hydrographs are aligned for easy comparison of the timing and magnitude of the stages and flows between the lakes.

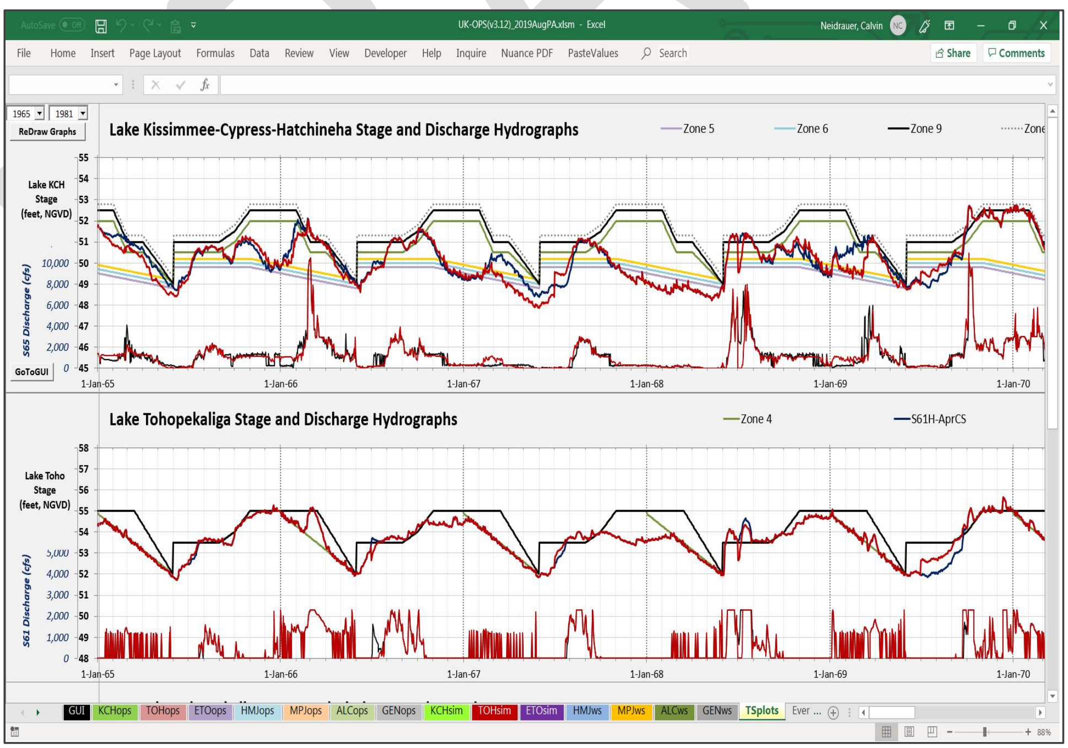
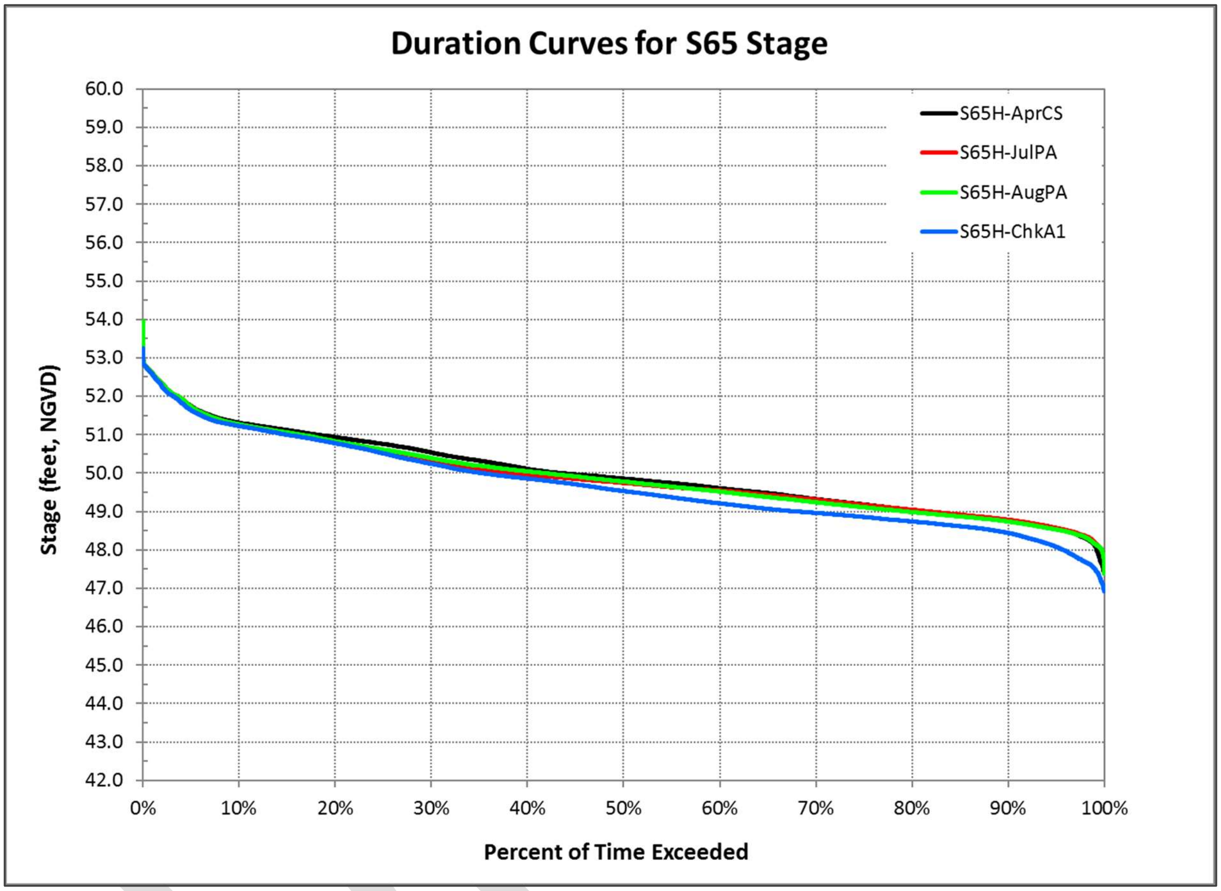


Figure 5-1. Sample stage and discharge hydrographs for Lakes Kissimmee, Cypress, and Hatchineha (top) and Lake Tohopekaliga (bottom).

3789 ### *5.2.2 Stage and Flow Duration*

3790 The StageDur and FlowDur worksheets can be accessed using the Stage Duration and Flow Duration buttons, respectively. Duration curves display the sorted output series, similar to a cumulative probability distribution function. The duration curves show the data range and indicate the value distribution. **Figures 5-2** and **5-3** are example stage and duration curves for KCH and S-65, respectively. The plots include options to select one of the three large lake systems and to turn on/off particular simulations.

3795


3796 Figure 5-2. Sample stage duration curves for Lakes Kissimmee, Cypress, and Hatchineha.

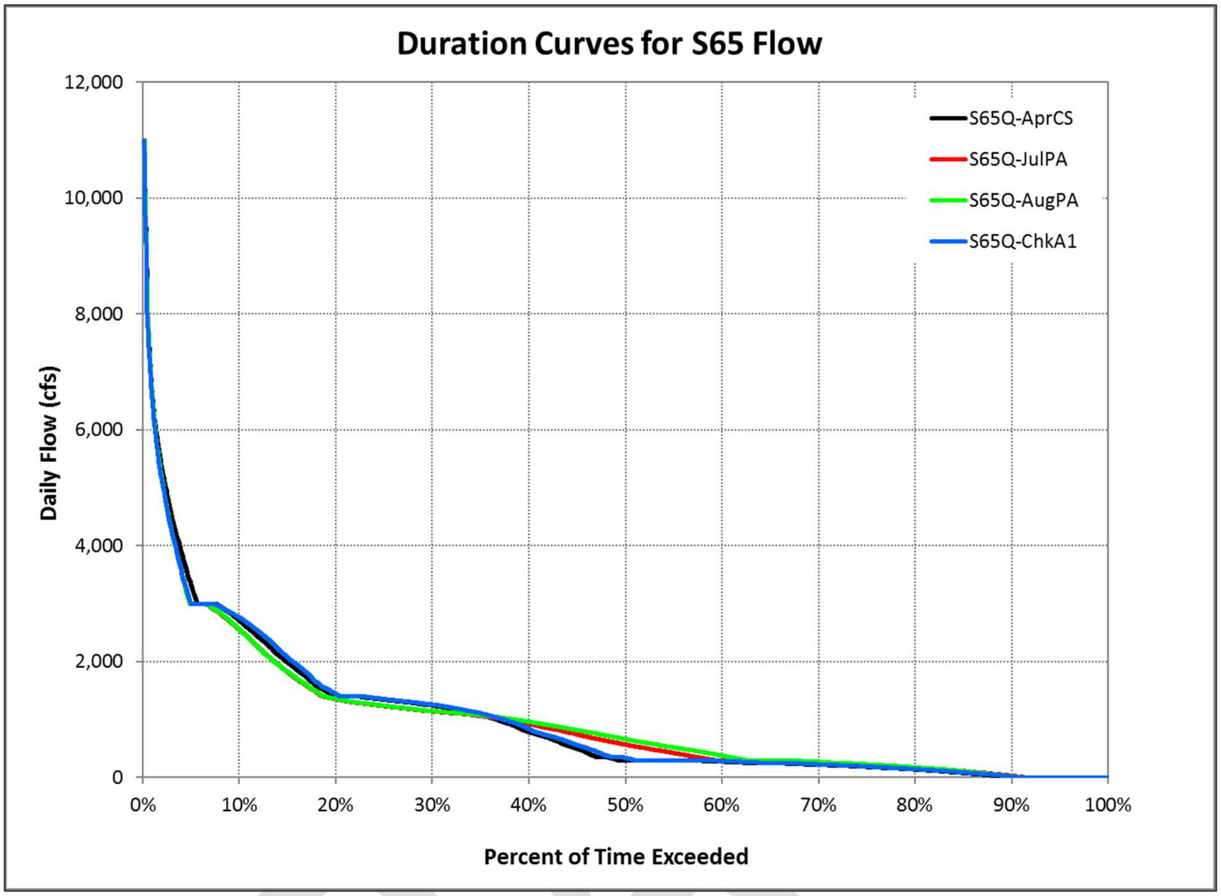


Figure 5-3. Sample flow duration curves for the S-65 structure.

5.2.3 Stage and Flow Percentiles

The StagePercsKCH, StagePercsTOH, and StagePercsETO worksheets contain charts of the stage percentiles for KCH, TOH, and ETO, respectively. These worksheets can be accessed using the corresponding KCH Stage Percentiles, TOH Stage Percentiles, and ETO Stage Percentiles buttons. Similarly, the FlowPercsKCH, FlowPercsTOH, and FlowPercsETO worksheets display flow percentiles for KCH, TOH, and ETO, respectively.

Percentiles are not hydrographs; rather, they are statistical summaries of the stage or flow distribution each day of the year. Percentiles are computed using all the years in the output; thus, for a 49-year simulation, each of the 365 days would have 49 data values for calculating each percentile statistic. The charts then connect the same percentile values for each day and display the iso-percentile curves. The percentile charts are helpful, particularly for position analysis simulations, to determine the probability of stages or flows exceeding particular values over time.

Figures 5-4 and **5-5** display example percentile plots for ETO stage and for KCH flow at the S-65 structure, respectively. The plots include options to specify the time window, percentiles of interest, and simulations to compare. The sample figures show outputs from a position analysis simulation, which initialized each of the 49 one-year simulations on July 1. The percentile plots also can be used for period-of-record simulations (i.e., a single 49-year simulation). Such plots are sometimes called cyclic analysis plots.

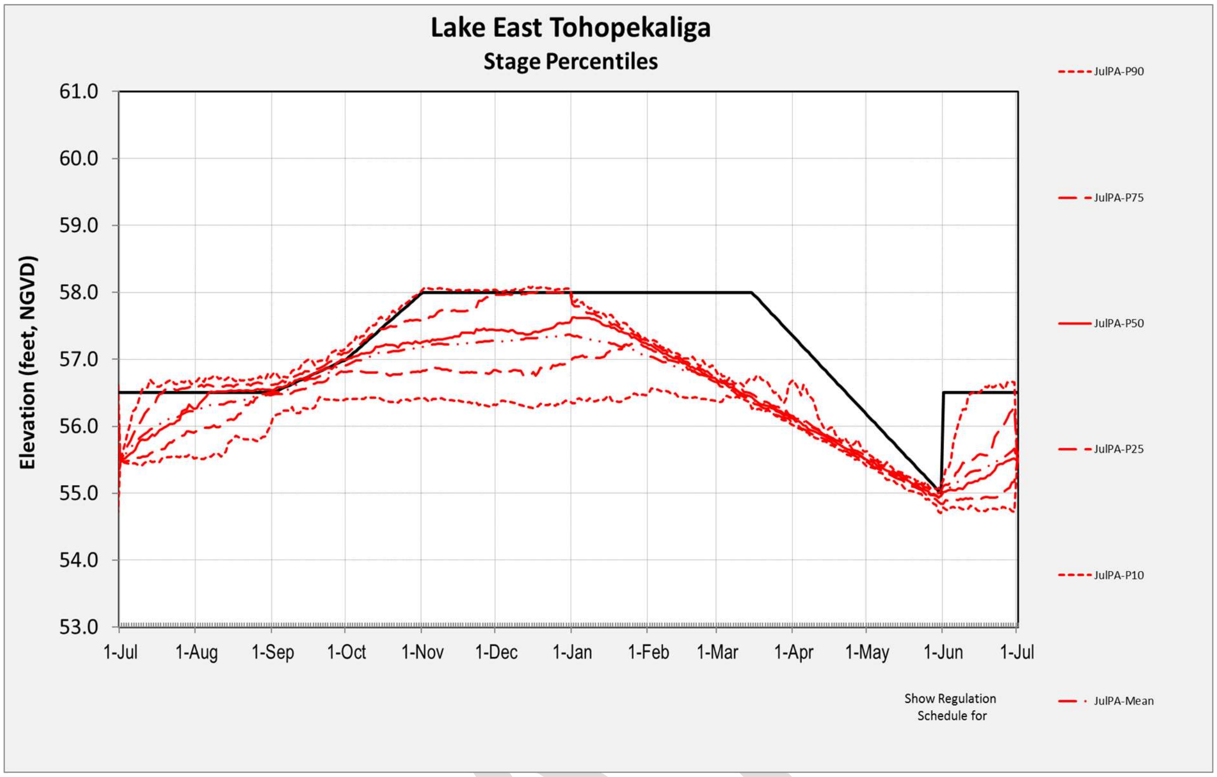


Figure 5-4. Sample stage percentile plot for East Lake Tohopekaliga.

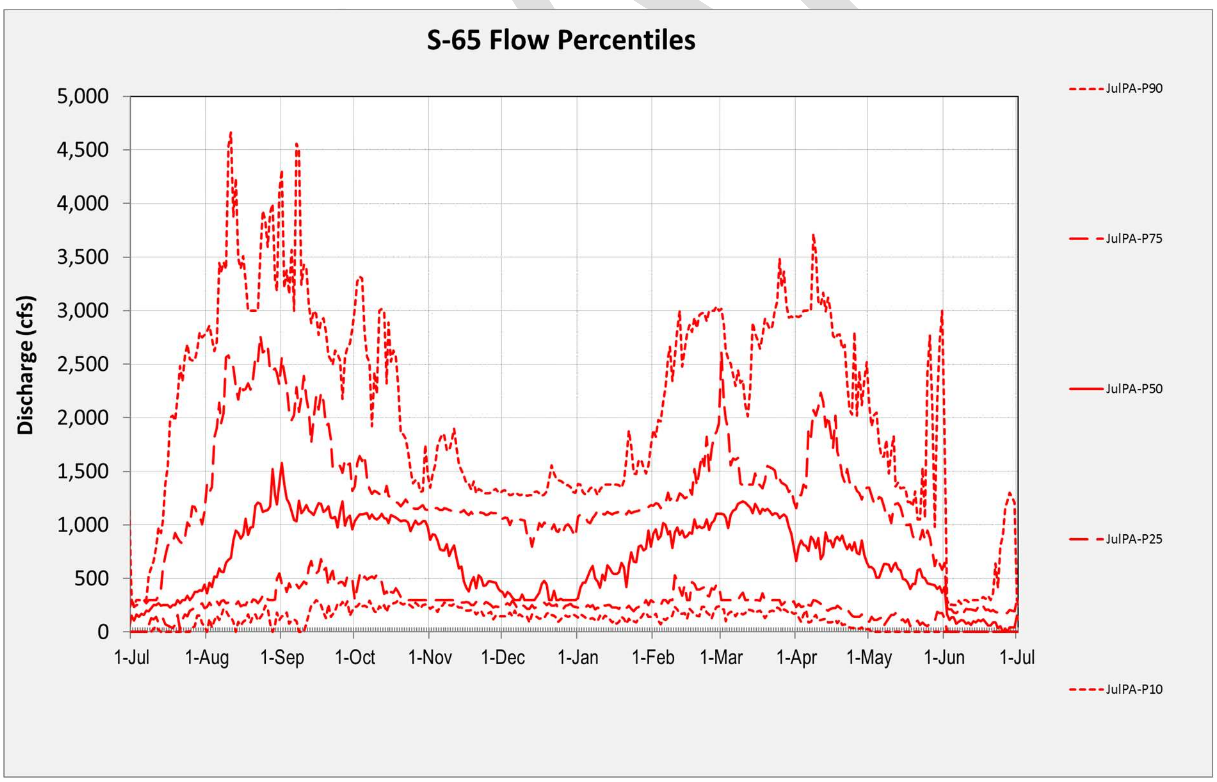


Figure 5-5. Sample flow percentile plot for Lakes Kissimmee, Cypress, and Hatchineha flows at the S-65 structure.

5.3 Hydrologic Performance Summaries

The UK-OPS Model automatically generates several measures of performance, most of which are derivatives of the fundamental stage and flow outputs and surrogates for ecological and/or water supply performance. New measures of performance typically are created based on the user's needs. Because the UK-OPS Model is a Microsoft Excel® application, modifying it to incorporate new measures, if desired, is relatively easy.

5.3.1 Water Budgets

The WatBuds worksheet can be accessed using the Water Budgets button. This worksheet contains charts that display the annual series of simulated water budget components for KCH, TOH, and ETO. **Figure 5-6** is an example showing KCH and TOH. The charts display the inflow components (WNI+RF and structure inflows) as positive values above the x-axis and the outflow components (ET, structure outflows, and water supply withdrawals) as negative values below the x-axis. Each year shows these components as stacked bars. The water year starts with the first month of position analysis simulations. For period-of-record simulations, the water year starts in January.

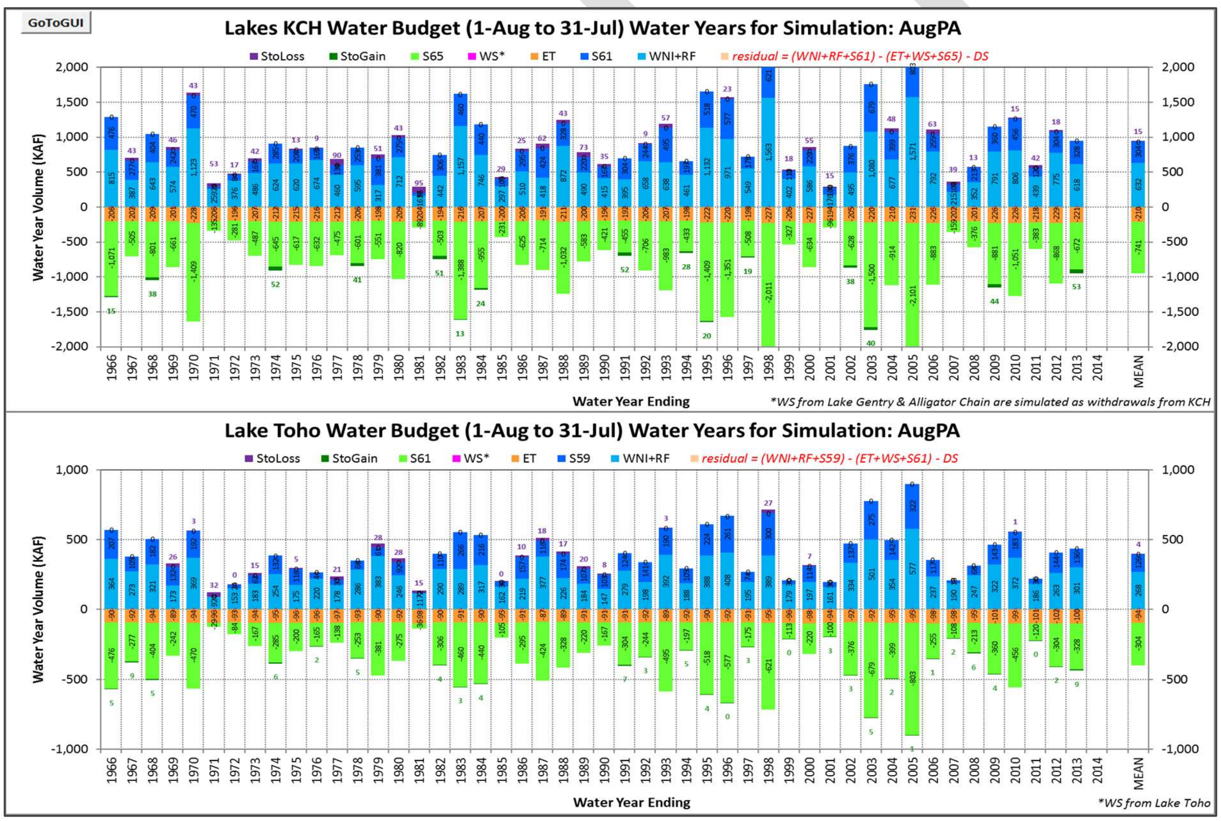


Figure 5-6. Sample water budgets for Lakes Kissimmee, Cypress, and Hatchineha and Lake Tohopekaliga.

For years with inflows exceeding outflows, the storage gain is displayed at the bottom of the bars. For years with outflows exceeding inflows, the storage loss is displayed at the top of the bars. Thus, the height of the positive components should always equal the height of the negative components. If the heights differ, then there is a problem with the mass balance. The residual term should always be zero and is displayed on the budget chart as a data label along the x-axis. Mass is conserved if the residual is zero, and non-zero values indicate a possible error in the mass balance, which would require correction prior to using the simulation results. Good modeling practice includes verifying mass conservation for every simulation; these charts help make that check.

5.3.2 Event Table and Plot

The Events worksheet can be accessed using the Event Table & TS Plot button. This worksheet enables analysis of user-specified stage and flow events for KCH, TOH, and ETO. The upper half of the worksheet allows selection of the site and data type, stage or flow threshold and whether to count events above or below the threshold, definition of a significant event duration, and optional specification of a seasonal window to limit the analysis. The lower half of the worksheet displays a time series of the events (**Figure 5-7**). The chart uses rectangles to indicate the start and end dates of each event, and the rectangle height represents the average magnitude of each event. Event summary statistics are shown on the left margin of the chart for each simulation. Note that the graphic is not generic enough to allow particular simulation outputs to be turned off. Furthermore, results for position analysis simulations may not be meaningful unless the event window is selected to not overlap with the start date of the 1-year position analysis simulations.

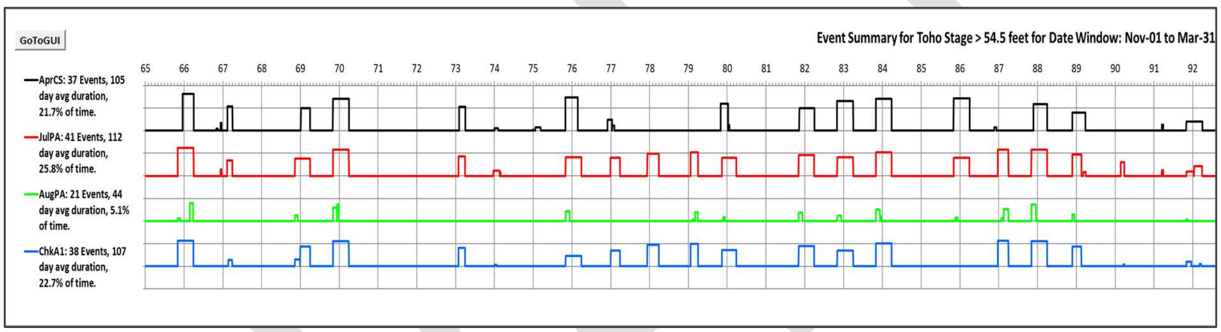


Figure 5-7. Sample event summary for Lake Tohopekaliga simulated stage.

5.3.3 Max D-day Inundation

The MaxStages worksheet can be accessed using the Max D-day Inundation button. This worksheet enables analysis of the maximum yearly stage that occurred for a user-specified minimum duration of consecutive days and during a user-specified date window. The example chart in **Figure 5-8** shows a sample for KCH. The specified duration (D) was 30 days. The date window was August 1 to December 31. The chart compares four simulations year-by-year by showing the yearly maximum stage meeting the aforementioned criteria. The chart also has a dropdown menu to select the desired large lake system. Some of the less frequently used parameter inputs (e.g., the date window) are located under the chart and can be changed by temporarily moving the chart. Dropdown menus can be added to enable easier selection of the date window.

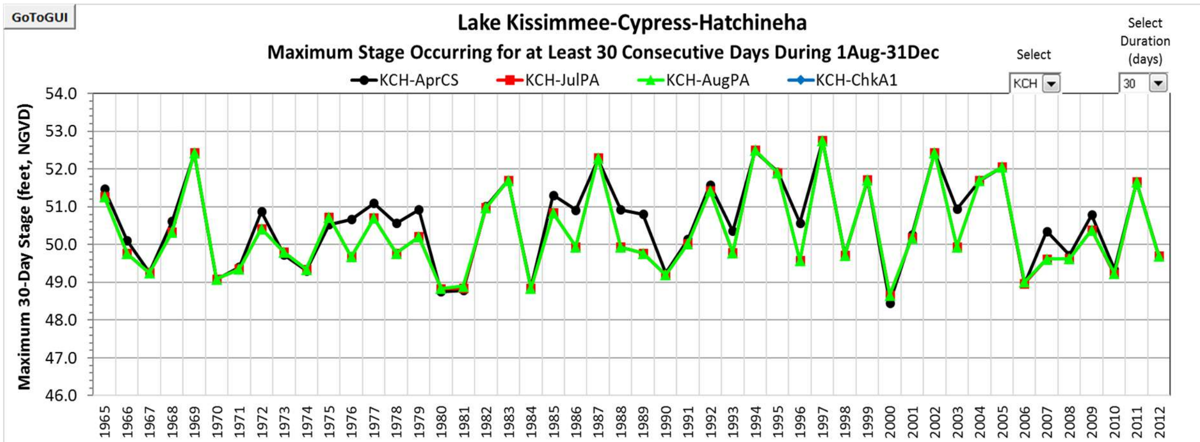


Figure 5-8. Sample maximum annual stage comparison at Lakes Kissimmee, Cypress, and Hatchineha.

An additional chart is displayed in the MaxStages worksheet to make relative comparisons between simulations (**Figure 5-9**). The annual values from the maximum stage chart for a prescribed baseline (AprCS in this example) are subtracted from the year-by-year values of the other simulations. Then the distribution of the yearly differences is displayed for each simulation using box and whisker plots. This relative performance comparison is similar to calculations for a paired T-test and helps illustrate the magnitude of the difference in maximum stages across the entire simulation period.

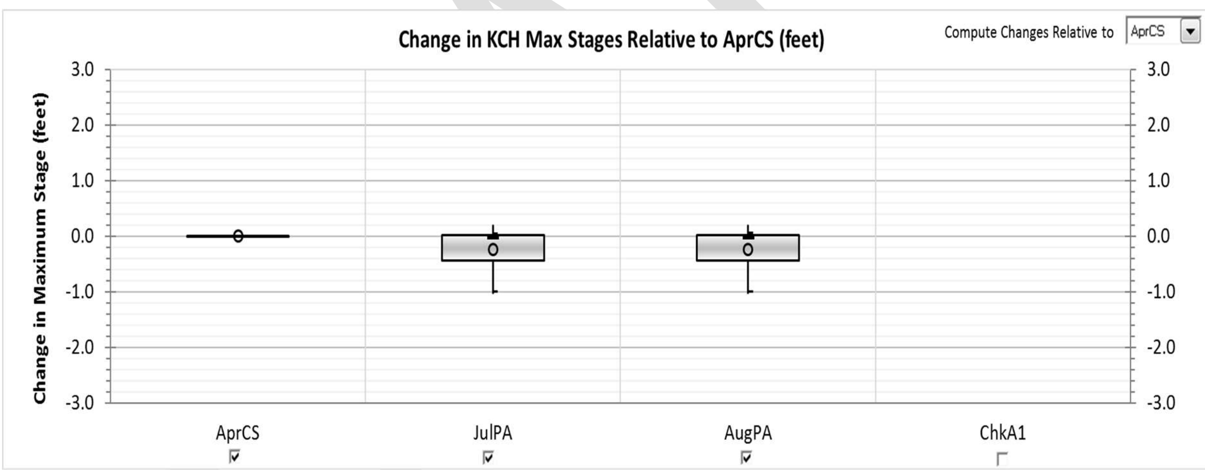


Figure 5-9. Sample event summary for Lake Tohopekaliga simulated stage.

A final note about the above two charts pertains to the check boxes located below the simulation names at the bottom of **Figure 5-9**. The check boxes control the display of the simulation output. The simulation named “ChkA1” is not displayed on either chart.

5.3.4 S-65 Annual Flow

The S65VolComp worksheet can be accessed using the S65 Annual Flow button. This worksheet enables evaluation of the effects of upstream operations and/or water supply withdrawals on the annual S-65 outflows from KCH.

The KRCOL Water Reservation set a maximum S-65 flow reduction limit of 5% for the period between 1965 and 2005. The baseline for evaluating proposed water supply withdrawals is the mean annual simulated S-65 flow for that period. The baseline simulation used historical data for WNI+RF, assumed the future expected operation under the authorized Headwaters Revitalization Schedule for KCH, and assumed the current authorized regulation schedules for ETO and TOH. The 41-year mean annual S-65 flow from this baseline simulation is 704,000 acre-feet/year.

The performance metric shown in **Figure 5-10** was developed for the UK-OPS Model to compare simulations of proposed water supply withdrawals with the baseline flow limit. The chart shows the distribution of annual simulated flow at the S-65 structure via box and whisker plots. The mean annual flow is shown as a labeled dot on the plots. The x-axis labels display the percent change relative to the baseline simulation 41-year mean. The ChkHRS simulation in **Figure 5-10** represents the baseline condition. The mean for the ChkHRS simulation is 704,000 acre-feet/year and the percent change on the axis label is zero.

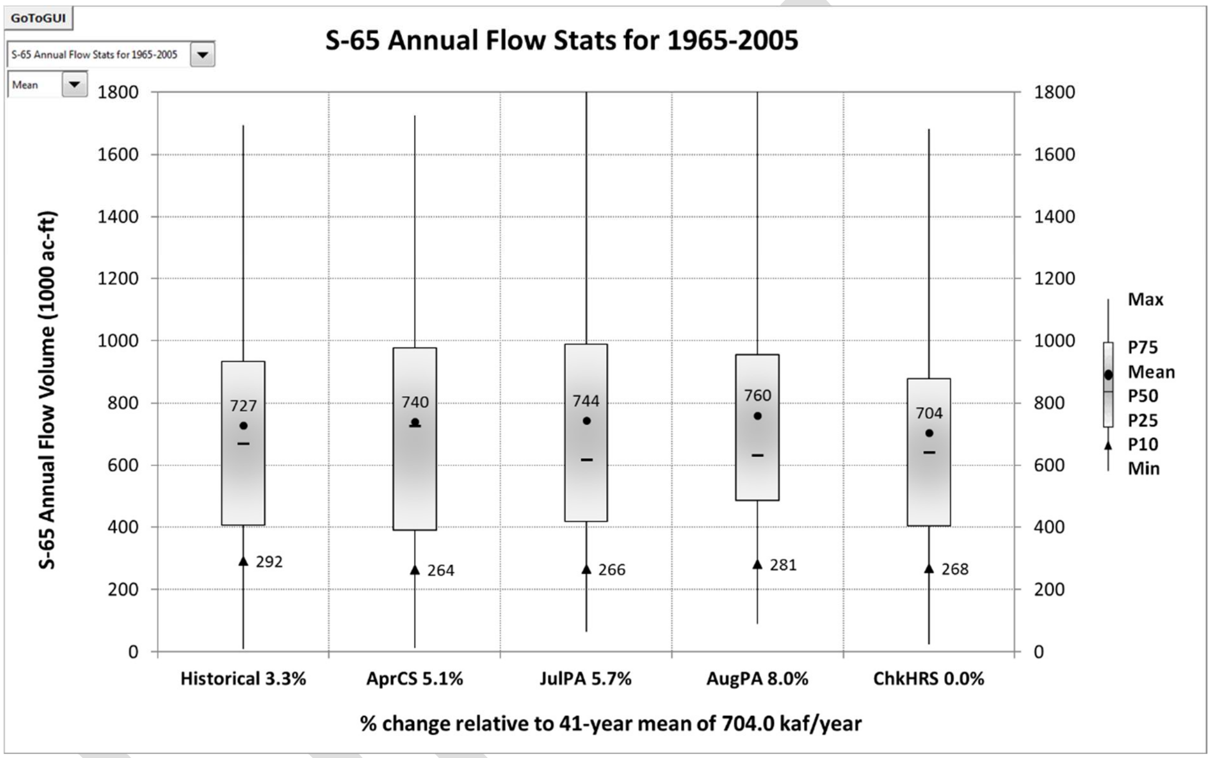


Figure 5-10. Sample annual flow statistics for the S-65 structure.

5.3.5 Water Supply Reliability

The WS_Table worksheet can be accessed using the WS Reliability button. This worksheet contains a table showing the number of days per month that water supply withdrawals occurred during the simulation. User controls allow specification of the lake system of interest: TOH, ETO, HMJ, MPJ, ALC, or GEN. Water withdrawals from KCH are not allowed by the draft KRCOL Water Reservation rules, so KCH is not included in the table. User controls also enable selection of the simulation name, a target reliability (percentage of time with water supply withdrawals) for computing performance, and the period for computing summary statistics.

Table 5-1 is an example water supply reliability table for a TOH water supply withdrawal scenario. The shaded cell values indicate the number of days in each month of each simulation year that water withdrawals occurred. The greens designate more days of withdrawals, whereas the oranges/reds indicate fewer days. The right side of the table summarizes the volumes withdrawn and the percent of time they occurred by season and by year. The summary at the bottom shows frequency statistics and the number of years that meet the user-specified reliability.

Table 5-1. Sample water supply reliability table for Lake Tohopekaliga.

Lake TOH Water Supply Reliability Table for JF_WS

No. of Days per Month with Lake Toho WS Withdrawals at 23.2 cfs (15.0 MGD)													Days	Vol(kaf)	AvgMGD	Percent of Time WS Withdrawal CalYear	WetSeas	DrySeas	WatYear
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	May-Oct	Nov-Apr	May-Apr
1965	0	5	16	22	28	1	13	31	8	12	0	16	152	7.00	6.25	41.6%	50.5%		
1966	11	6	7	22	31	14	31	24	9	6	0	0	161	7.41	6.62	44.1%	62.5%	43.9%	42.5%
1967	0	15	18	22	24	1	13	31	20	1	0	0	145	6.68	5.96	39.7%	48.9%	37.3%	46.6%
1968	0	0	0	12	26	27	31	31	10	0	0	0	137	6.31	5.61	37.4%	67.9%	17.8%	27.9%
1969	23	9	6	22	29	1	0	0	6	30	8	6	140	6.45	5.75	38.4%	35.9%	42.0%	50.7%
1970	7	6	7	22	23	1	4	20	0	0	0	0	90	4.14	3.70	24.7%	26.1%	37.3%	33.4%
1971	0	0	0	3	18	0	0	0	0	0	0	0	21	0.97	0.86	5.8%	9.8%	9.9%	14.0%
1972	0	0	0	21	23	5	31	26	8	0	0	0	114	5.25	4.67	31.1%	50.5%	20.7%	10.7%
1973	0	25	18	21	23	1	0	16	30	5	0	0	139	6.40	5.71	38.1%	40.8%	41.0%	43.0%
1974	0	1	13	30	29	3	31	31	14	1	0	0	153	7.04	6.29	41.9%	59.2%	34.4%	32.6%
1975	0	0	0	22	28	1	0	30	24	8	5	0	118	5.43	4.85	32.3%	49.5%	23.6%	35.9%
1976	5	19	7	22	25	16	31	28	10	1	0	0	164	7.55	6.72	44.8%	60.3%	39.0%	40.7%
1977	7	23	7	23	27	1	0	5	15	4	0	3	115	5.29	4.73	31.5%	28.3%	41.0%	46.8%
1978	23	17	7	21	28	1	12	29	4	0	0	0	142	6.54	5.84	38.9%	40.2%	46.7%	33.7%
1979	4	28	12	22	31	1	0	2	27	9	0	0	136	6.26	5.59	37.3%	38.0%	45.8%	38.4%
1980	21	11	8	21	27	1	0	0	0	0	0	0	89	4.10	3.65	24.3%	15.2%	41.3%	35.8%
1981	0	0	0	0	6	1	0	3	29	1	0	14	54	2.49	2.22	14.8%	21.7%	2.8%	7.7%
1982	18	7	6	21	31	30	21	21	9	4	0	0	168	7.73	6.90	46.0%	63.0%	45.8%	29.0%
1983	9	17	7	21	29	22	30	21	9	6	7	6	184	8.47	7.56	50.4%	63.6%	39.2%	46.6%
1984	7	7	8	22	29	1	29	30	7	0	0	0	140	6.45	5.74	38.3%	52.2%	40.4%	47.5%
1985	0	0	3	30	26	1	6	31	26	2	0	0	125	5.75	5.14	34.2%	50.0%	27.8%	35.3%
1986	23	7	7	23	25	0	0	23	17	0	0	0	125	5.75	5.14	34.2%	35.3%	40.1%	41.6%
1987	30	12	6	21	29	1	0	0	0	0	20	21	140	6.45	5.75	38.4%	16.3%	46.2%	36.7%
1988	6	7	8	22	26	1	0	12	28	0	2	22	134	6.17	5.49	36.6%	36.4%	51.6%	31.1%
1989	7	4	10	22	26	0	0	18	20	9	0	0	116	5.34	4.77	31.8%	39.7%	43.9%	36.7%
1990	0	4	31	23	23	1	0	21	3	0	0	0	106	4.88	4.36	29.0%	26.1%	38.2%	35.9%
1991	0	0	20	30	31	30	23	21	5	9	0	0	169	7.78	6.95	46.3%	64.7%	38.2%	26.8%
1992	0	13	21	20	30	13	31	27	9	4	6	10	184	8.47	7.54	50.3%	62.0%	39.4%	47.3%
1993	7	6	6	22	27	1	9	3	15	0	0	0	96	4.42	3.95	26.3%	29.9%	39.6%	46.8%
1994	1	28	14	21	29	22	28	20	8	4	10	7	192	8.84	7.89	52.6%	60.3%	43.9%	32.6%
1995	7	7	7	22	29	1	6	31	23	7	8	6	154	7.09	6.33	42.2%	52.7%	42.0%	46.8%
1996	7	7	7	21	30	25	27	20	8	7	0	0	159	7.32	6.52	43.4%	63.6%	40.4%	41.8%
1997	11	16	7	21	31	1	19	30	7	0	1	26	170	7.83	6.99	46.6%	47.8%	40.6%	47.1%
1998	7	6	7	22	28	1	0	0	5	7	0	0	83	3.82	3.41	22.7%	22.3%	45.8%	43.0%
1999	0	25	18	22	28	4	31	29	15	7	7	7	193	8.88	7.93	52.9%	62.0%	43.9%	29.0%
2000	7	7	8	22	26	1	0	10	14	0	0	0	95	4.37	3.89	26.0%	27.7%	39.4%	47.0%
2001	0	0	0	13	24	1	28	27	17	2	0	0	112	5.16	4.60	30.7%	53.8%	17.5%	17.5%
2002	0	18	18	22	22	16	31	26	9	2	12	6	182	8.38	7.48	49.9%	57.6%	37.7%	43.0%
2003	7	7	6	22	30	23	27	19	9	4	2	15	171	7.87	7.03	46.8%	60.9%	42.5%	45.5%
2004	7	7	7	22	30	1	28	30	13	8	7	7	167	7.69	6.84	45.6%	59.8%	42.3%	47.0%
2005	7	6	7	21	31	28	20	20	2	7	12	7	168	7.73	6.90	46.0%	58.7%	40.6%	45.2%
2006	8	7	7	22	27	0	19	16	29	0	0	0	135	6.21	5.55	37.0%	49.5%	42.5%	46.8%
2007	0	25	16	22	20	24	31	23	13	3	1	1	179	8.24	7.36	49.0%	62.0%	39.2%	42.2%
2008	12	15	8	21	26	1	12	30	21	5	0	0	151	6.95	6.19	41.3%	51.6%	39.4%	47.0%
2009	0	2	14	30	28	30	28	21	9	1	0	12	175	8.06	7.19	47.9%	63.6%	34.9%	38.6%
2010	13	6	5	21	31	30	23	2	0	2	0	0	133	6.12	5.47	36.4%	47.8%	41.5%	47.7%
2011	0	15	26	22	25	1	18	31	19	7	6	4	174	8.01	7.15	47.7%	54.9%	41.5%	41.4%
2012	3	14	8	22	26	6	31	31	13	3	0	0	157	7.23	6.43	42.9%	59.8%	39.0%	43.2%
2013	0	0	13	30	30	24	31	24	9	3	0	0	164	7.55	6.74	44.9%	65.8%	34.4%	41.9%
MEANS																			
48YR	6	10	9	21	27	9	16	20	12	4	2	4	140	6.46	5.76	38.4%	47.5%	37.5%	38.4%
41YR	7	9	9	21	27	7	14	19	12	4	3	4	137	**6.29**	**5.61**	**37.4%**	45.7%	37.4%	37.4%

SUMMARY STATISTICS	**CalYear**	**WetSeas**	**DrySeas**	**WatYear**
No. of years used for stats	**49**	**49**	**48**	**48**
Years used for stats	**'65-'13**	**'65-'13**	**'66-'13**	**'66-'13**
# Yrs with WS duration > 50%	**4**	**26**	**1**	**1**
Annual Exceedance Frequency	**8.2%**	**53.1%**	**2.1%**	**2.1%**
Return Period (1-in-Nyrs)	**12.3**	**1.9**	**48.0**	**48.0**

5.3.6 Seasonal Distributions of Stage and Flow

The BoxWhiskerStage and BoxWhiskerFlow worksheets can be accessed using the Mon-Stage BoxWhisker and Mon-Flow BoxWhisker buttons, respectively. The stage chart compares the average daily stage for each month of each simulation (**Figure 5-11**). The flow chart compares the mean daily flow for each month of each simulation (**Figure 5-12**). These charts allow comparison of the monthly distributions for the user-specified simulations and sites; they also show the seasonal distributions of stages and flows. The box and whisker plots within each month are not labeled but are in the same order as shown in the legend.

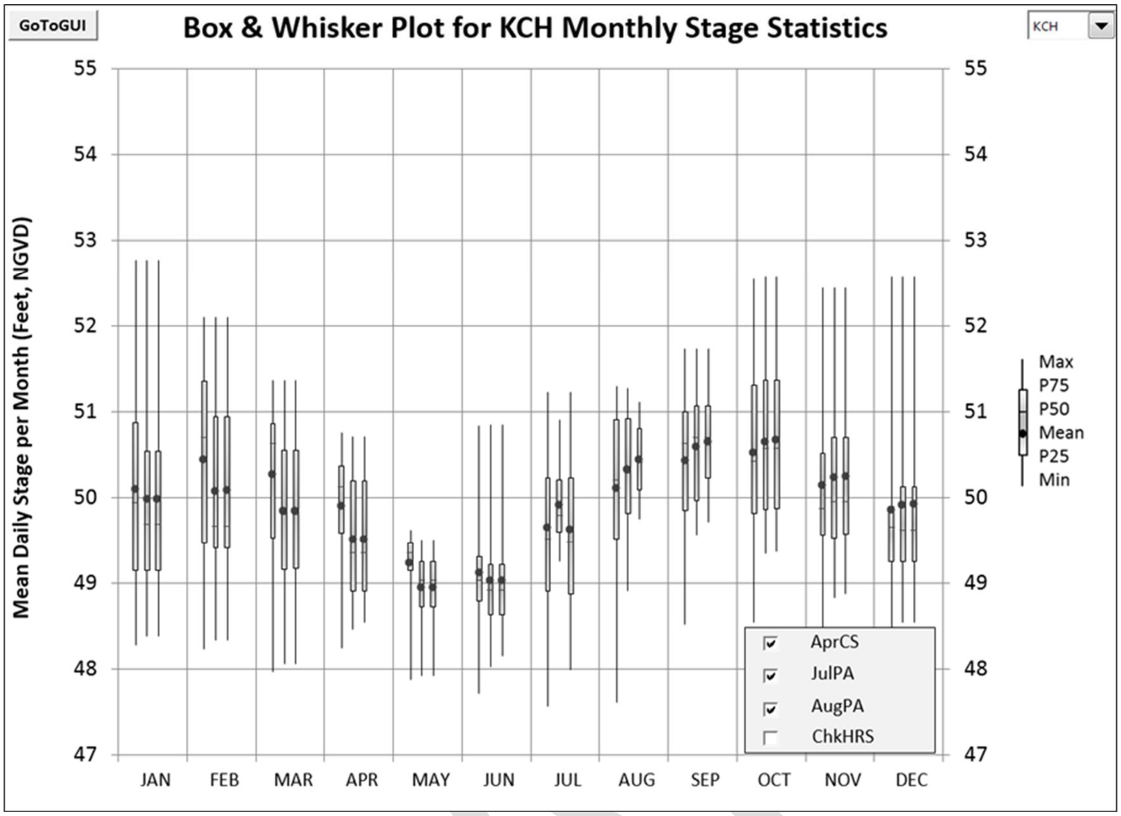


Figure 5-11. Sample monthly stage distributions at Lakes Kissimmee, Cypress, and Hatchineha.

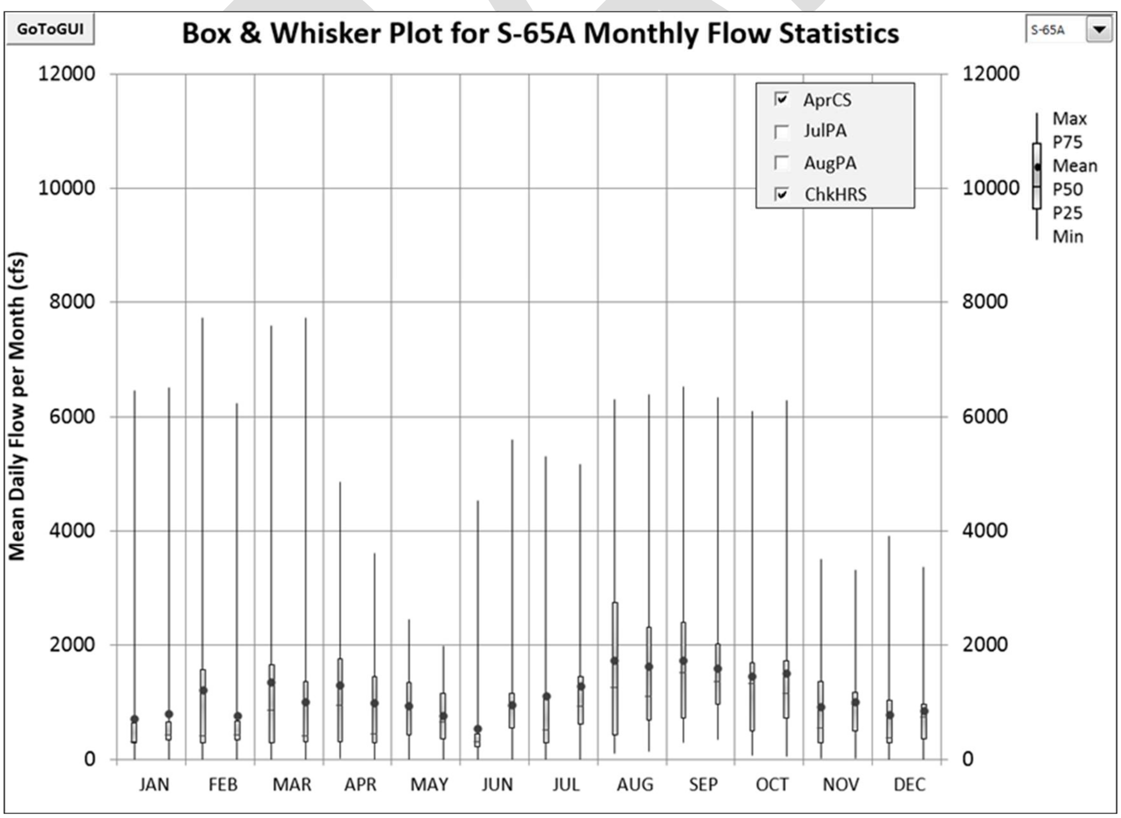


Figure 5-12. Sample monthly flow distributions at the S-65A structure.

6 MODEL VALIDATION

This section compares UK-OPS Model outputs to corresponding input data to demonstrate that the model produces reliable outputs. As described in **Sections 1** and **4**, the UK-OPS Model does not simulate the rainfall-runoff hydrologic process. Instead, it computes watershed inflows to each lake using key hydrologic information from detailed hydrologic models or the historical record. The version of the UK-OPS Model described in this report used the historical data record as the input data set for calculating the boundary condition inflows, namely the WNI+RF. Thus, the UK-OPS Model is not calibrated and validated in the same way as the supporting hydrologic models.

A validation simulation was performed that set the simulated outflows from the UKB's three large lake systems equal to the outflows used to calculate the boundary conditions (WNI+RF). This test aimed to validate the routing calculations by demonstrating the simulated stages were consistent with historical stages.

6.1 Lake Stage Comparisons

By setting the simulated outflows equal to the outflows used to calculate the boundary conditions (WNI+RF), the routing equations were expected to replicate the stage series used to calculate the boundary inflows. For the version of the UK-OPS Model described in this report, historical data were used to calculate the boundary conditions.

Figures 6-1 and **6-2** illustrate the stage and discharge hydrographs for KCH, TOH, and ETO for the first and last 8 years, respectively, of the 49-year simulation. The red traces represent the validation simulation (Val1), and they completely coincide with, and cover, the black traces representing the historical data (Hist). From these comparisons it is concluded that the routing equations in the UK-OPS Model are correct.

Figures 6-3, **6-4**, and **6-5** show the stage duration curves for KCH, TOH, and ETO, respectively, for the entire 49-year simulation period. These figures also show the red curves for the validation simulation completely coincide with, and cover, the black traces representing the historical values.

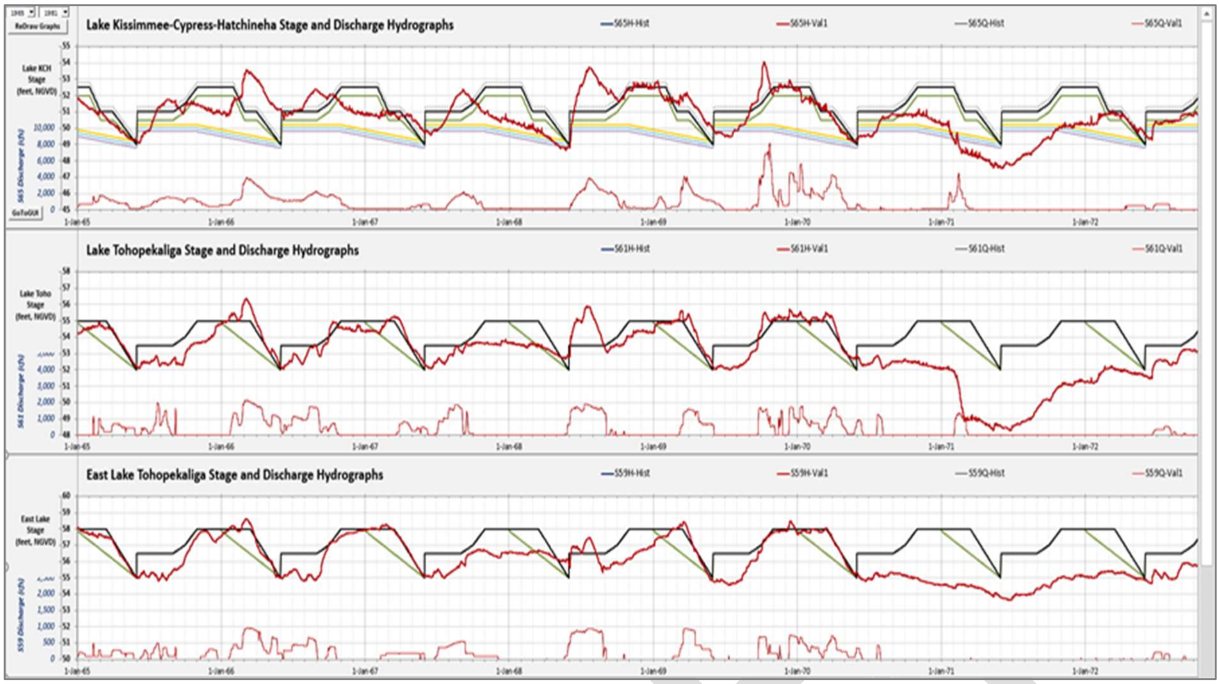


Figure 6-1. Simulated validation (red) and historical (black) hydrographs for 1965 to 1972.

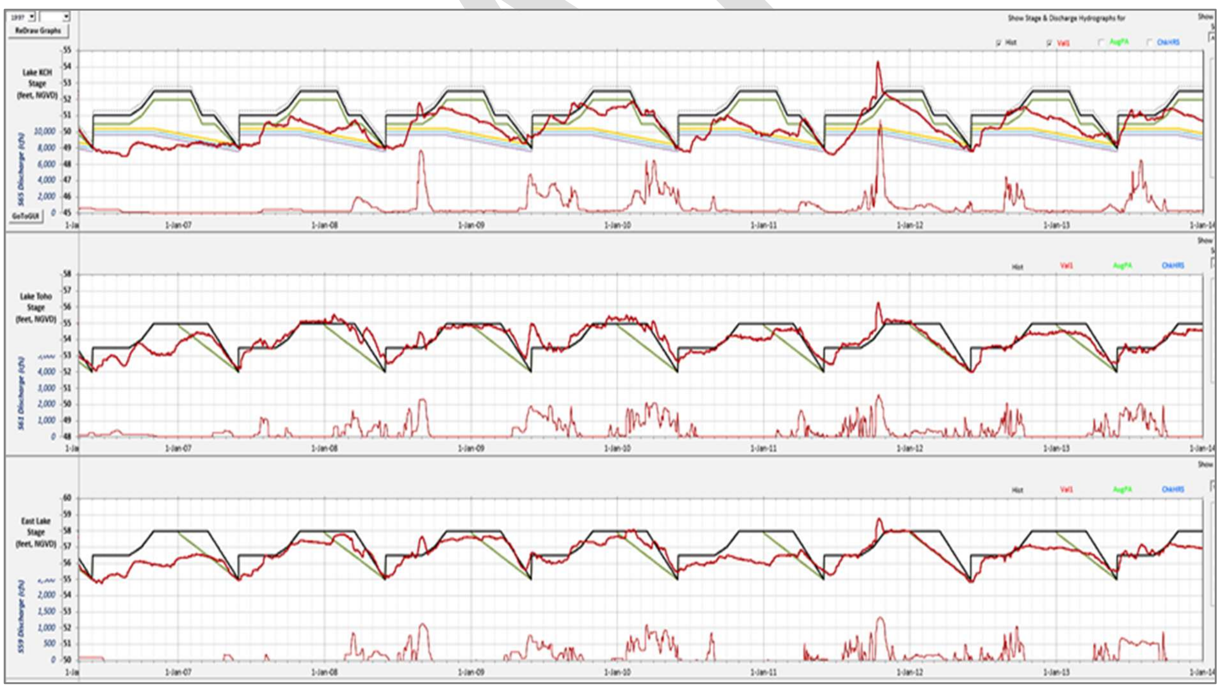
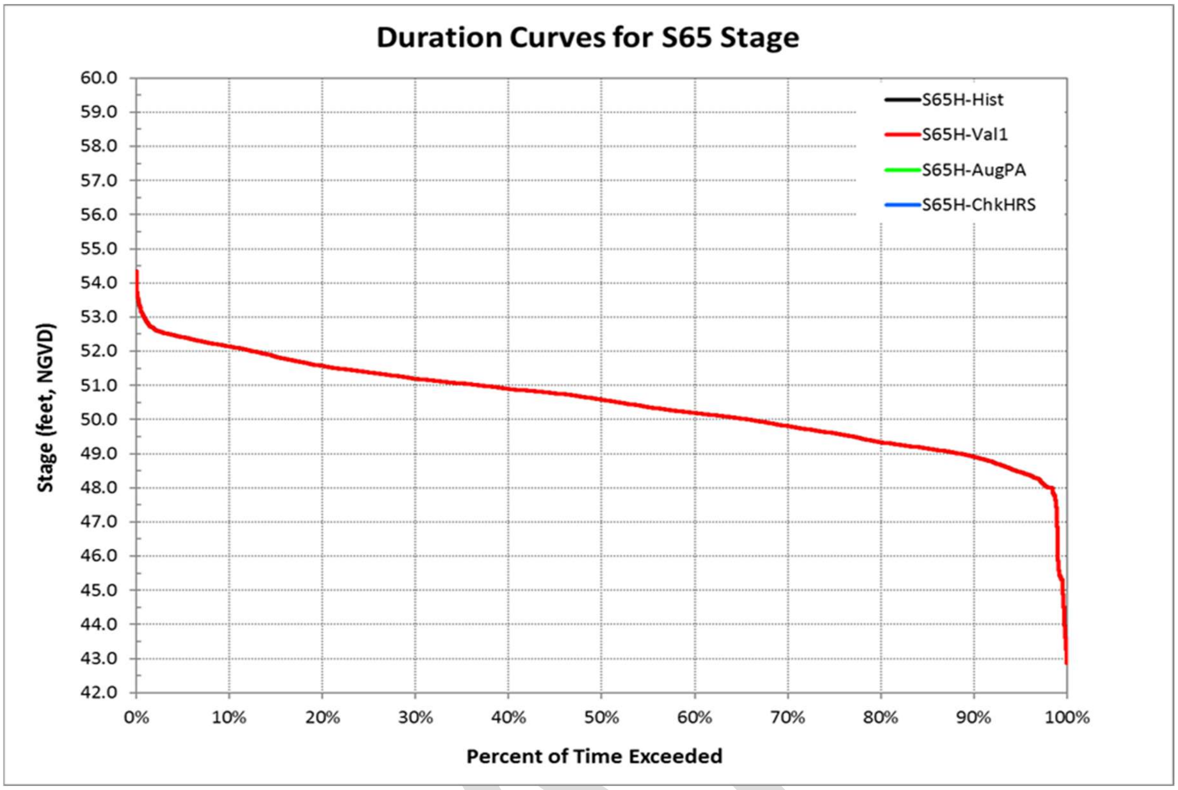
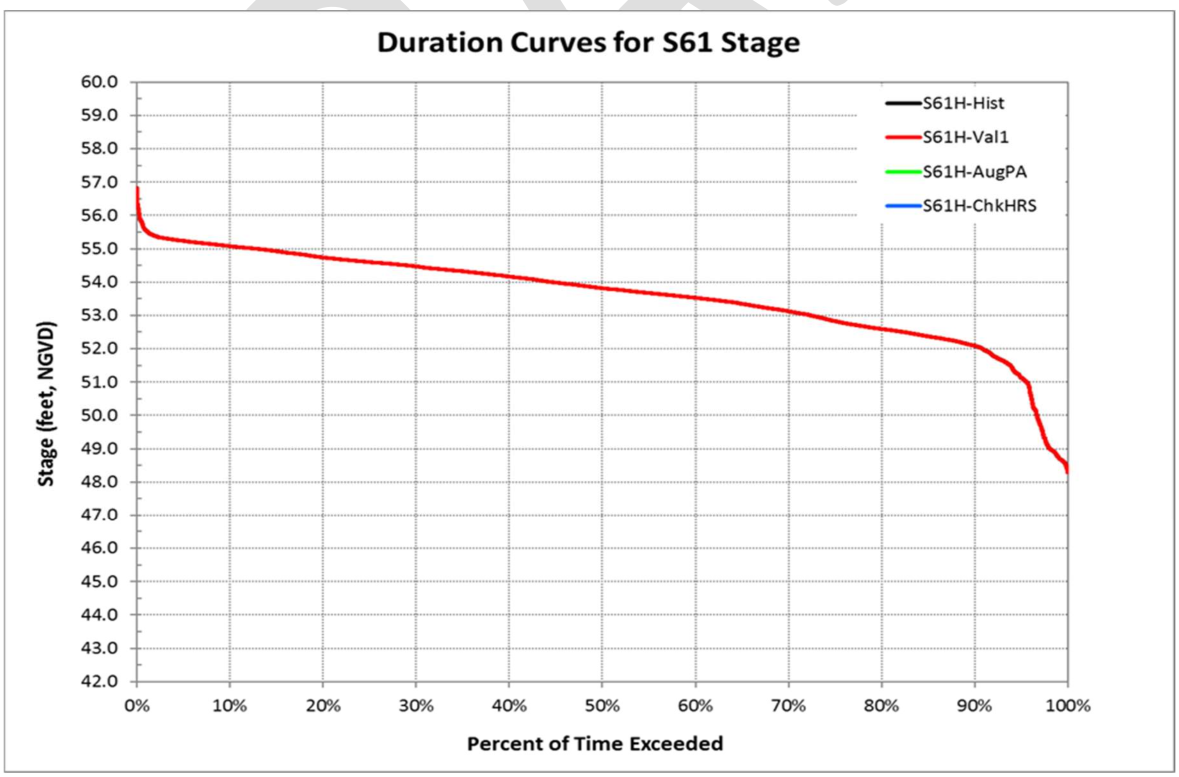


Figure 6-2. Simulated validation (red) and historical (black) hydrographs for 2006 to 2013.



3957
3958 Figure 6-3. Lakes Kissimmee, Cypress, and Hatchineha stage duration curves: simulated validation (red) and historical (black; directly behind red line).
3959



3960
3961 Figure 6-4. Lake Tohopekaliga stage duration curves: simulated validation (red) and historical (black; directly behind red line).
3962

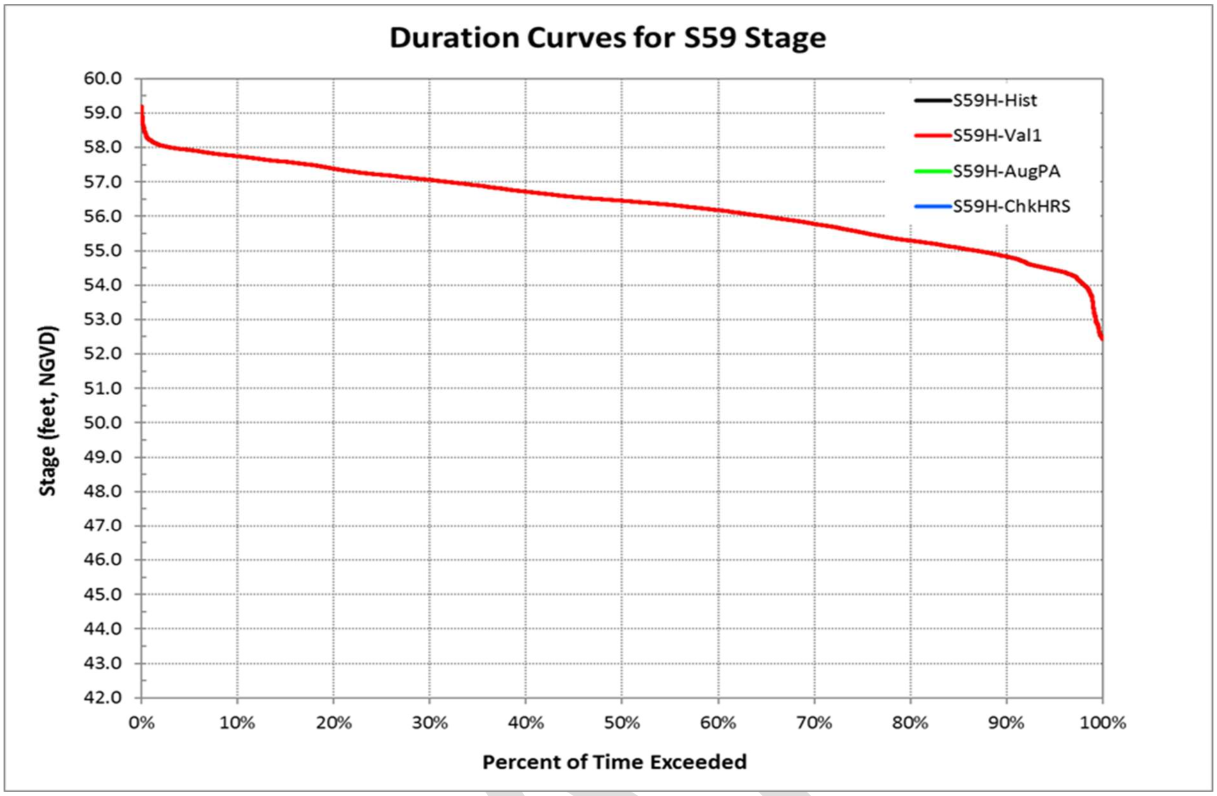


Figure 6-5. East Lake Tohopekaliga stage duration curves: simulated validation (red) and historical (black; directly behind red line).

6.2 Water Budget Comparisons

A fundamental requirement of any hydrologic model is that it conserves mass. In other words, the flows must be accounted for and the model should not create or destroy water (mass). **Figures 6-6**, **6-7**, and **6-8** compare the validation simulation and historical annual water budgets for KCH, TOH, and ETO, respectively. Residuals in the water balance are calculated as inflows minus outflows minus storage change, and zero values demonstrate mass balance. Inspection of these budgets shows identical results, verifying the validation simulation reproduces the historical input data and thus conserves mass.

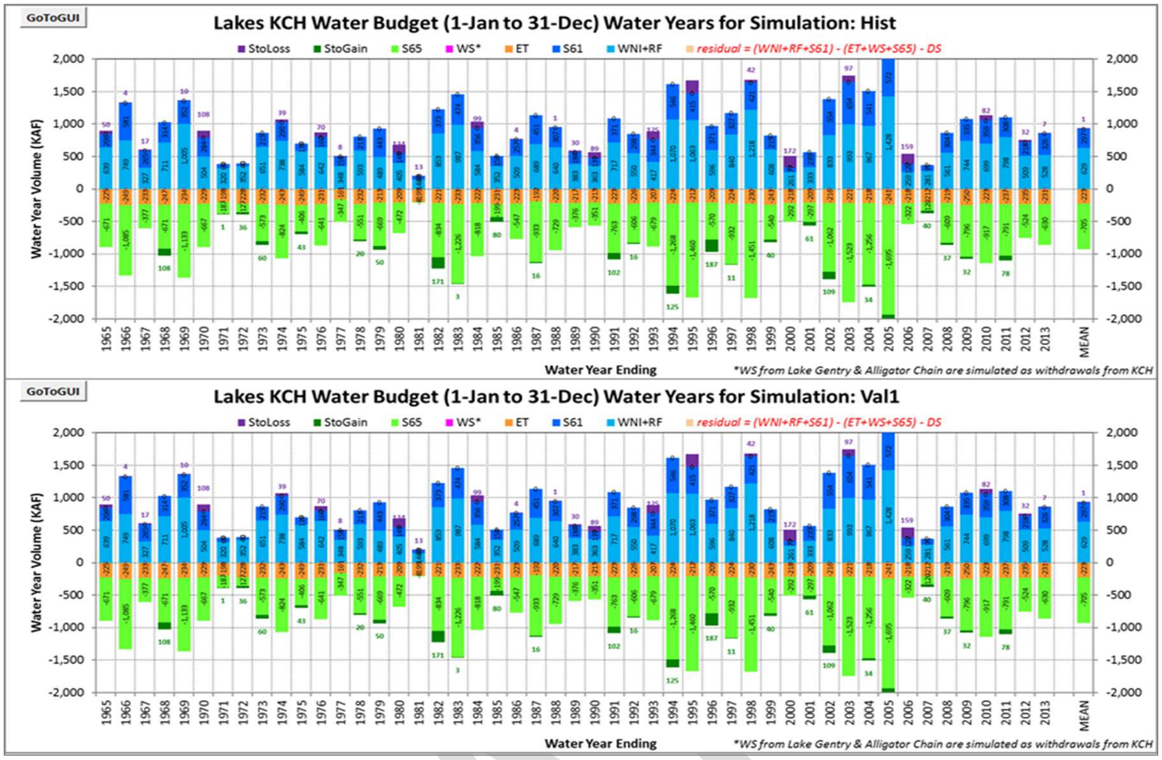


Figure 6-6. Lakes Kissimmee, Cypress, and Hatchineha annual water budgets: historical (top) and simulated validation (bottom).

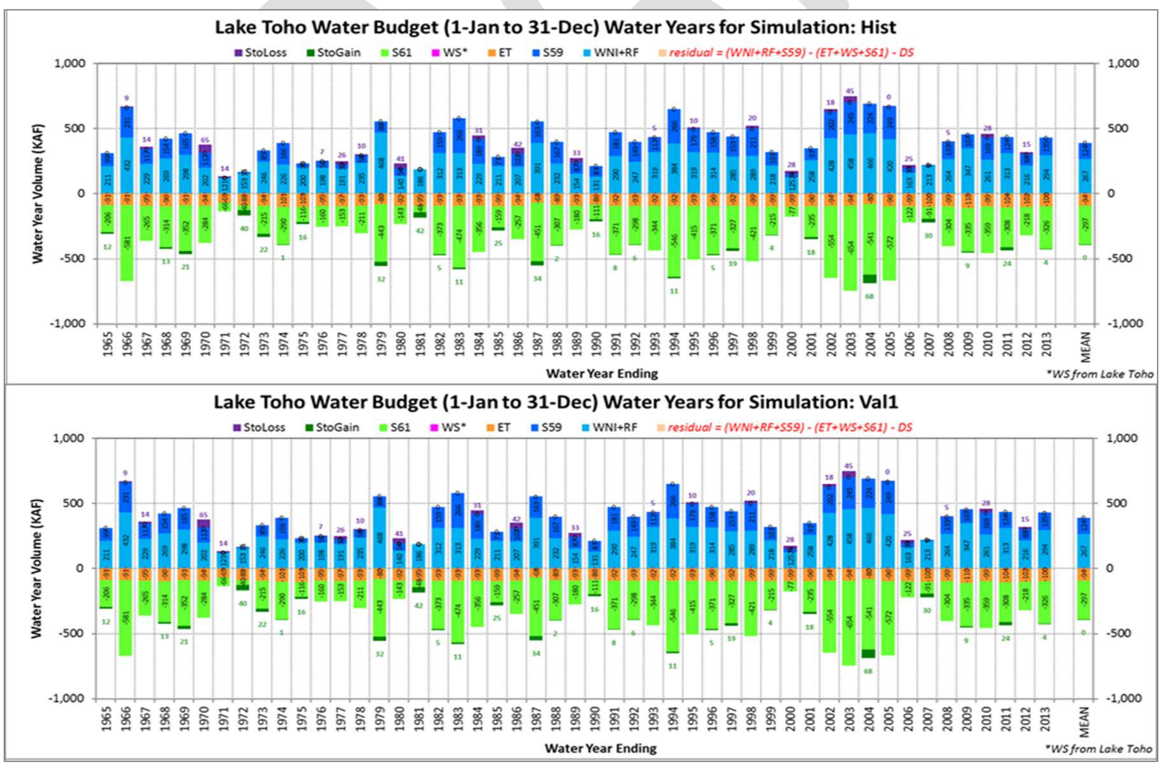


Figure 6-7. Lake Tohopekaliga annual water budgets: historical (top) and simulated validation (bottom).

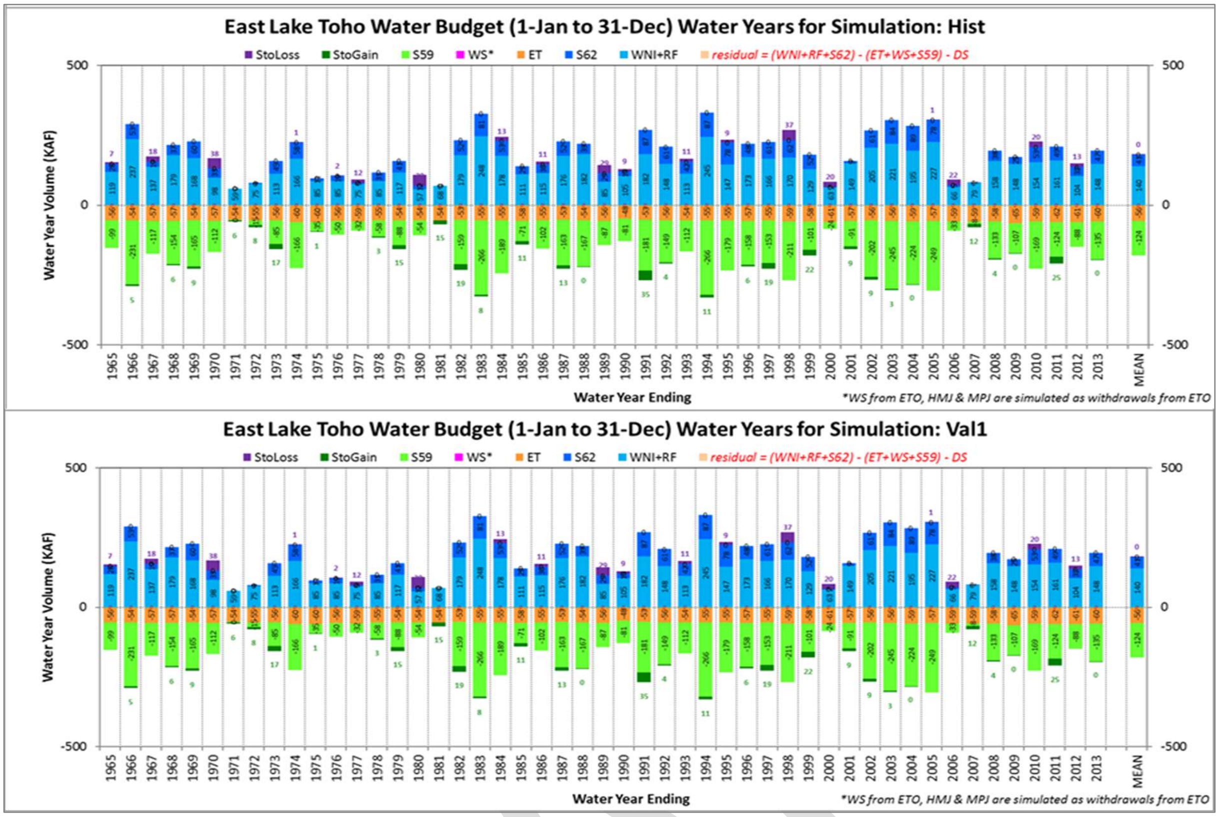


Figure 6-8. East Lake Tohopekaliga annual water budgets: historical (top) and simulated validation (bottom).

7 APPLICATIONS

The UK-OPS Model has been used for several applications since it was originally developed in 2014. This section briefly summarizes the purposes and findings from two of these applications to demonstrate some of the typical and appropriate uses of the model: 1) the SFWMD's monthly position analysis in support of the Operations Planning Program; and 2) a sensitivity analysis to demonstrate potential effects of the draft KRCOL Water Reservation rules from a hypothetical water withdrawal scenario.

Other applications of the UK-OPS Model not described in this report include: 1) pump sizing analysis to support the planning of the proposed ETO drawdown; 2) seasonal operations planning to design and evaluate alternative operations for KCH, TOH, and ETO; and 3) evaluation of the proposed Lake Toho Restoration/Alternative Water Supply Project. The Lake Toho Restoration/Alternative Water Supply Project evaluation was the first use of the UK-OPS Model to test impacts of proposed water withdrawals subject to the draft KRCOL Water Reservation rules.

7.1 SFWMD Position Analysis

Position analysis is a special form of risk analysis evaluated from the present position of the system. A position analysis evaluates water resource systems and the risks associated with operational decisions (Hirsh 1978). The SFWMD Dynamic Position Analysis (DPA) is an application of the South Florida Water Management Model (SFWMM) (SFWMD 2005) to estimate the probability distributions of stages and flows for Lake Okeechobee and the system south of the lake for the upcoming 11 months. The SFWMM DPA is deemed dynamic because it includes a 1-month warmup period to synchronize the simulated antecedent hydrology with the actual hydrology. Details of the DPA are available on the SFWMD's Operations Planning webpage: https://www.sfwmd.gov/science-data/operational-planning.

The SFWMM relies on S-65E boundary inflows from another model. The UK-OPS Model has provided the S-65 flow boundary condition since 2015 when it was discovered that the previous model, the Upper Kissimmee Chain of Lakes Routing Model (UKISS) significantly underestimated S-65 flows for the 1997-1998 El Niño (very wet) period. Because the UK-OPS Model had the option to base the UKB hydrology on historical data, it was selected to support the SFWMM DPA until detailed basin models were updated and recalibrated.

Whenever a DPA is needed, usually at beginning of each month, the following UK-OPS Model steps are executed to produce the S-65 flow series, which is further processed by a river routing model for the Lower Kissimmee Basin to yield the SFWMM boundary flows at the S-65E structure.

1. Review seasonal operating strategy and modify the UK-OPS Model assumptions, as necessary.

2. Determine the initial stage values using real-time posted stage values for KCH, TOH, and ETO, and enter initial stages and start date in the UK-OPS Model GUI.

3. Run the model and evaluate key performance metrics, including water budgets, stage and discharge hydrographs, and percentile plots.

4. Communicate results to the operations planning team for further processing and preparation of the SFWMM DPA. The **Attachment** contains an example email communicating the assumptions and results for the August 2019, UK-OPS Model position analysis simulations.

Figure 7-1 illustrates the S-65 flow percentile chart for the August position analysis simulation. The distribution shows the high variability in flow as early as 2 to 4 weeks after the August 1 initialization. It is important to note that the position analysis is not a forecast but rather a distribution of possible outcomes based on the variability of historical rainfall conditions.

Figures 7-2, **7-3**, and **7-4** show the stage percentile plots for the August position analysis simulations for ETO, TOH, and KCH, respectively. These percentile plots illustrate the distribution of stages each day of the 1-year look-ahead period. The charts represent the probability distributions of lake stages for each day of the upcoming year, assuming current initial conditions and the rainfall for each simulation year is equally likely to occur.

The percentile charts for TOH and ETO show the relatively tight distribution of stages during the January to May spring recession operation. The KCH percentiles show wide variability, particularly during the November to May dry season. Stages in KCH tend to track well-below the top of the regulation schedule because the operations are designed to discharge meaningful flows to the Kissimmee River when the stage is below the top of the regulation schedule.

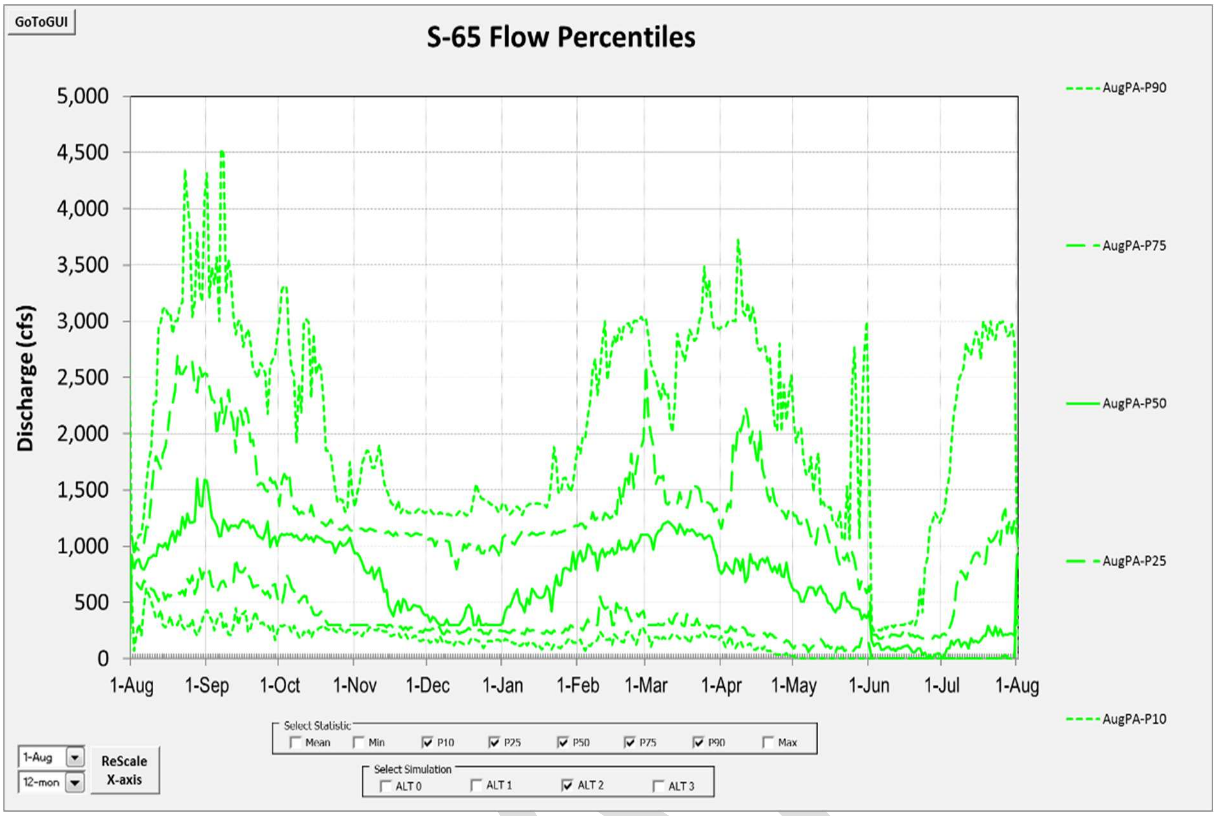


Figure 7-1. S-65 flow percentiles for the August 2019 position analysis.

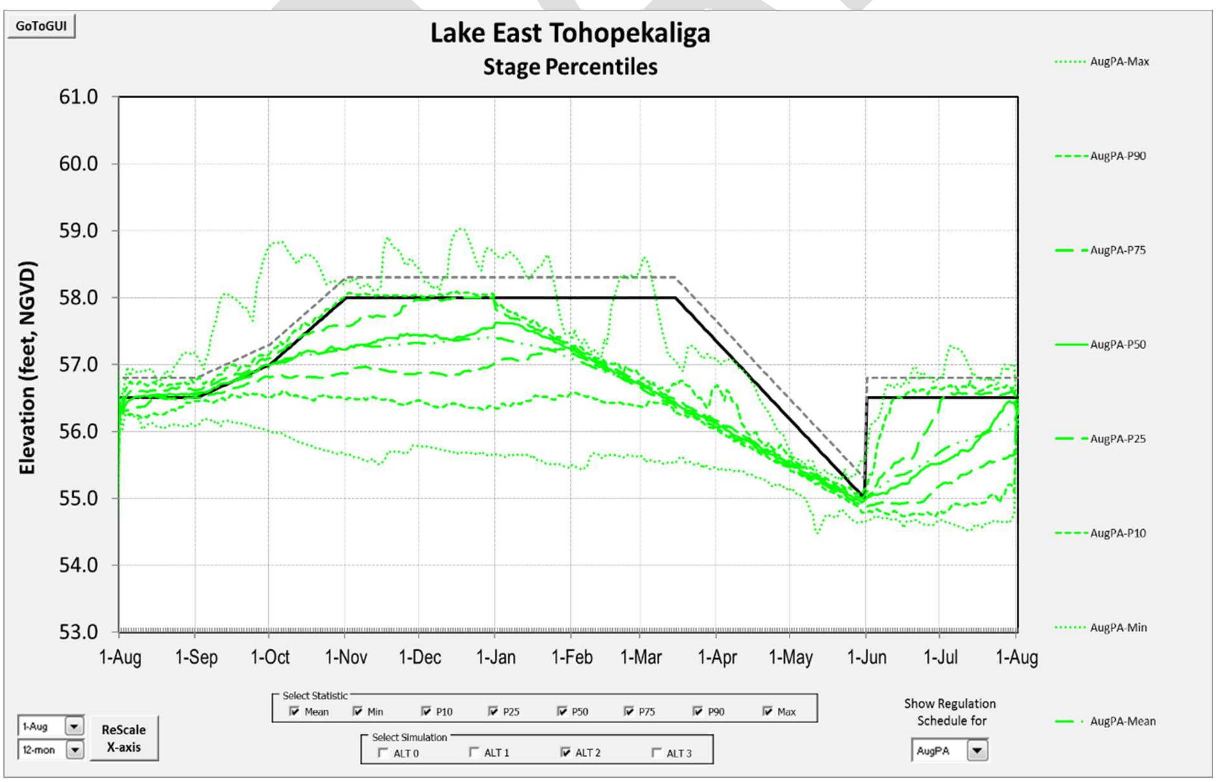


Figure 7-2. East Lake Tohopekaliga stage percentiles for the August 2019 position analysis.

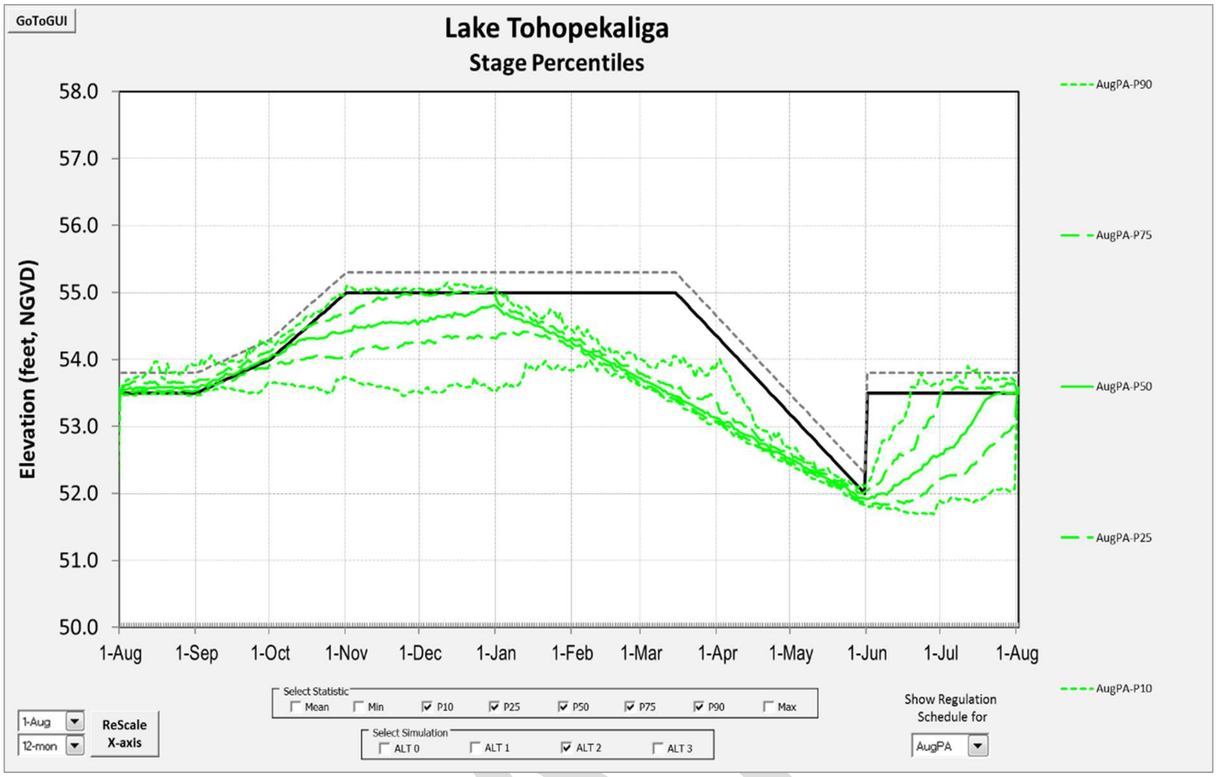


Figure 7-3. Lake Tohopekaliga stage percentiles for the August 2019 position analysis.

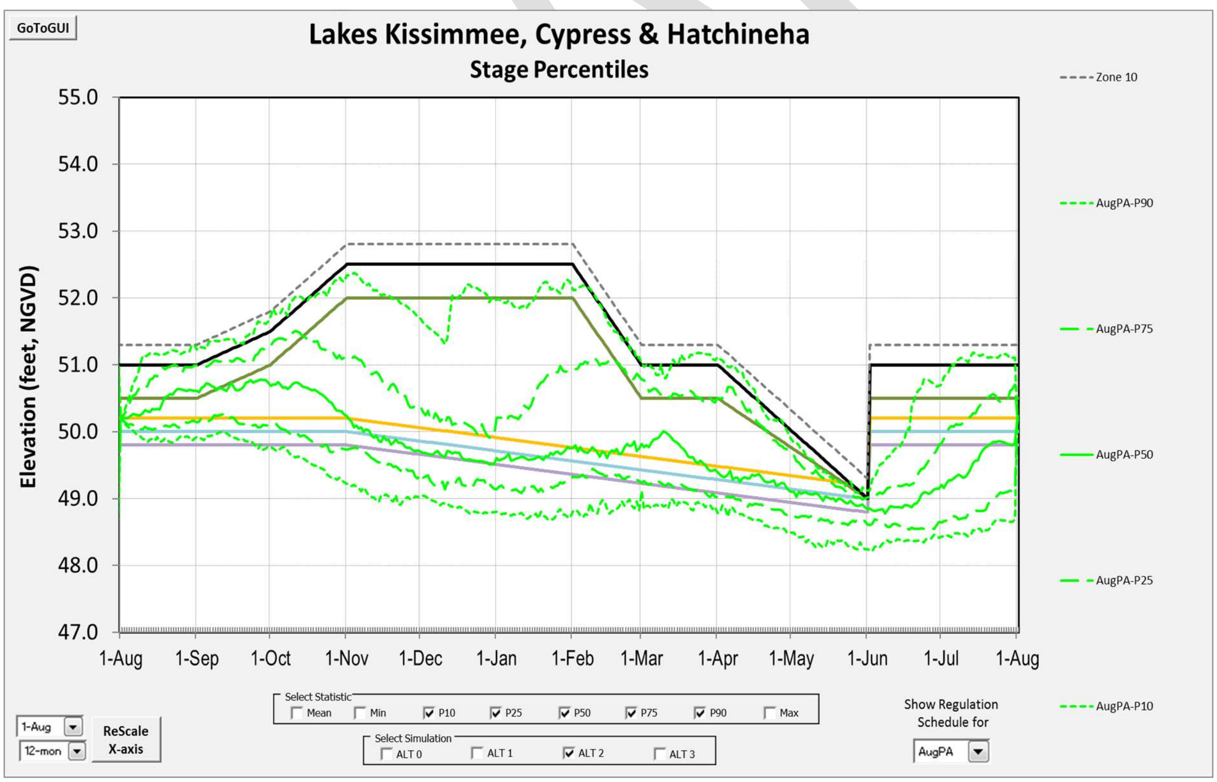


Figure 7-4. Lakes Kissimmee, Cypress, and Hatchineha stage percentiles for the August 2019 position analysis.

7.2 Sensitivity Analysis of Hypothetical Water Supply Withdrawals with Draft KRCOL Water Reservation Rule Criteria

This application of the UK-OPS Model investigated the effects of hypothetical water supply withdrawals from TOH with the draft KRCOL Water Reservation rule criteria. Water supply withdrawal reliability also was assessed with and without the proposed Lake Okeechobee constraint. Results of the sensitivity analysis are presented in this section, following a short summary of the components of the draft KRCOL Water Reservation rule criteria.

The draft KRCOL Water Reservation rules set WRLs in six of the lake systems in the UKB. **Figures 7-5** and **7-6** illustrate the WRLs for ETO and TOH, respectively. The red dashed line denotes the WRL, which was designed to protect the water needed for fish and wildlife of the lake system. The general concept is that water withdrawals can occur if the lake stage is above its respective WRL. However, there can be additional constraints on withdrawals. For example, if water withdrawals are considered for HMJ, then the stage in HMJ must exceed its WRL and the stage in ETO also may need to exceed its WRL. However, if Lake Okeechobee is not releasing water to the estuaries in order to manage the lake stage (i.e., regulatory discharges), then withdrawals from HMJ are restricted. If the all the conditions are met, then withdrawals can occur on that day. The process repeats each day of the simulation.

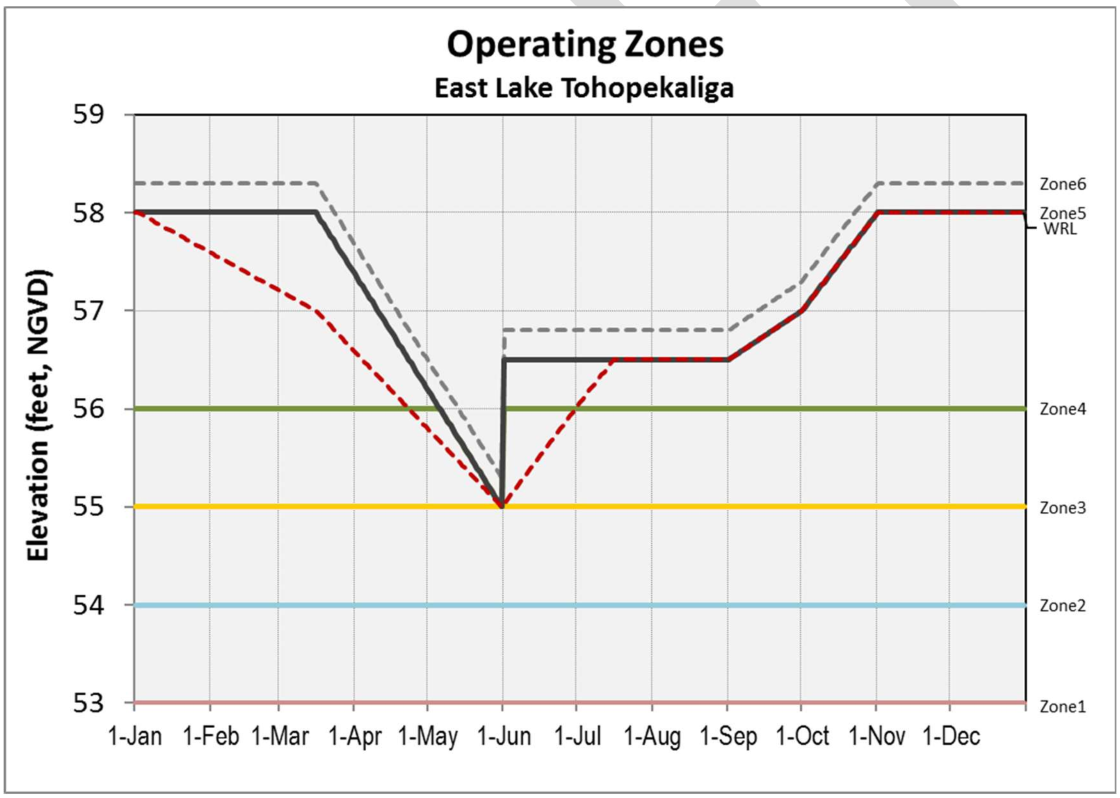


Figure 7-5. East Lake Tohopekaliga regulation schedule with proposed water reservation line (red dashed line).

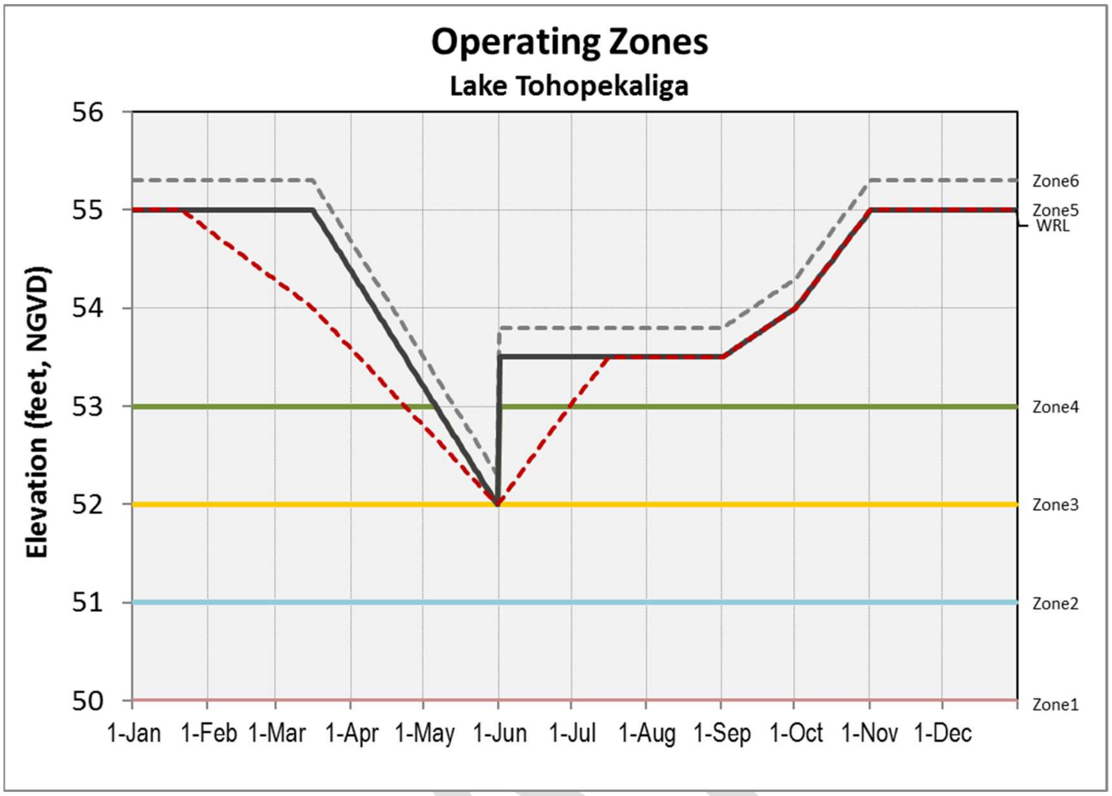


Figure 7-6. Lake Tohopekaliga regulation schedule with proposed water reservation line (red dashed line).

7.2.1 Baseline Scenario

The first scenario simulation (hereafter referred to as Base) was a baseline that used KCH Headwaters Regulation Schedule (**Figure 3-10**) and the standard regulation schedules for ETO and TOH (**Figures 3-1** and **3-5**, respectively; **Figures 7-5** and **7-6**, respectively). No water supply withdrawals were assumed.

7.2.2 Water Supply Withdrawal Scenario 1

Scenario 1, hereafter WSmax, used the same assumptions as Base but included water supply withdrawals from TOH. The capacity of the infrastructure needed to make the withdrawal was fixed at 64 million gallons per day (99 cfs), but the daily withdrawal rate was subject to the constraints of the draft KRCOL Water Reservation rules. No water supply withdrawals from the other lake systems were assumed in this hypothetical scenario.

7.2.3 Water Supply Withdrawal Scenario 2

Scenario 2, hereafter WSmaxL, was identical to the Scenario 1 except for the addition of the Lake Okeechobee constraint. The same baseline simulation (Base) was used for the relative comparison. Withdrawals from UKB lakes could reduce water availability downstream. The Lake Okeechobee constraint was designed to limit adverse impacts to permitted water users downstream of the UKB by limiting withdrawals from UKB lakes to when regulatory releases from Lake Okeechobee are being made to one or both of the coastal estuaries (Caloosahatchee River and/or St. Lucie Estuary).

The approximation of this constraint is depicted in **Figure 7-7**. The Lake Okeechobee hydrograph for a portion of the simulation of the 2008 Lake Okeechobee Regulation Schedule is colored green when the stage is above the Low Sub-band, indicating regulatory releases are being made to either the Caloosahatchee River or St. Lucie Estuary. The lake stage is colored red when the stage is below the Low Sub-band of the 2008 Lake Okeechobee Regulation Schedule, indicating relatively low water conditions with no regulatory releases being made to either the Caloosahatchee River or St. Lucie Estuary. When the lake stage is colored red, the Lake Okeechobee constraint is met, and no water supply withdrawals can be made from UKB lakes. When the stage is green, then water supply withdrawals can be made from UKB lakes.

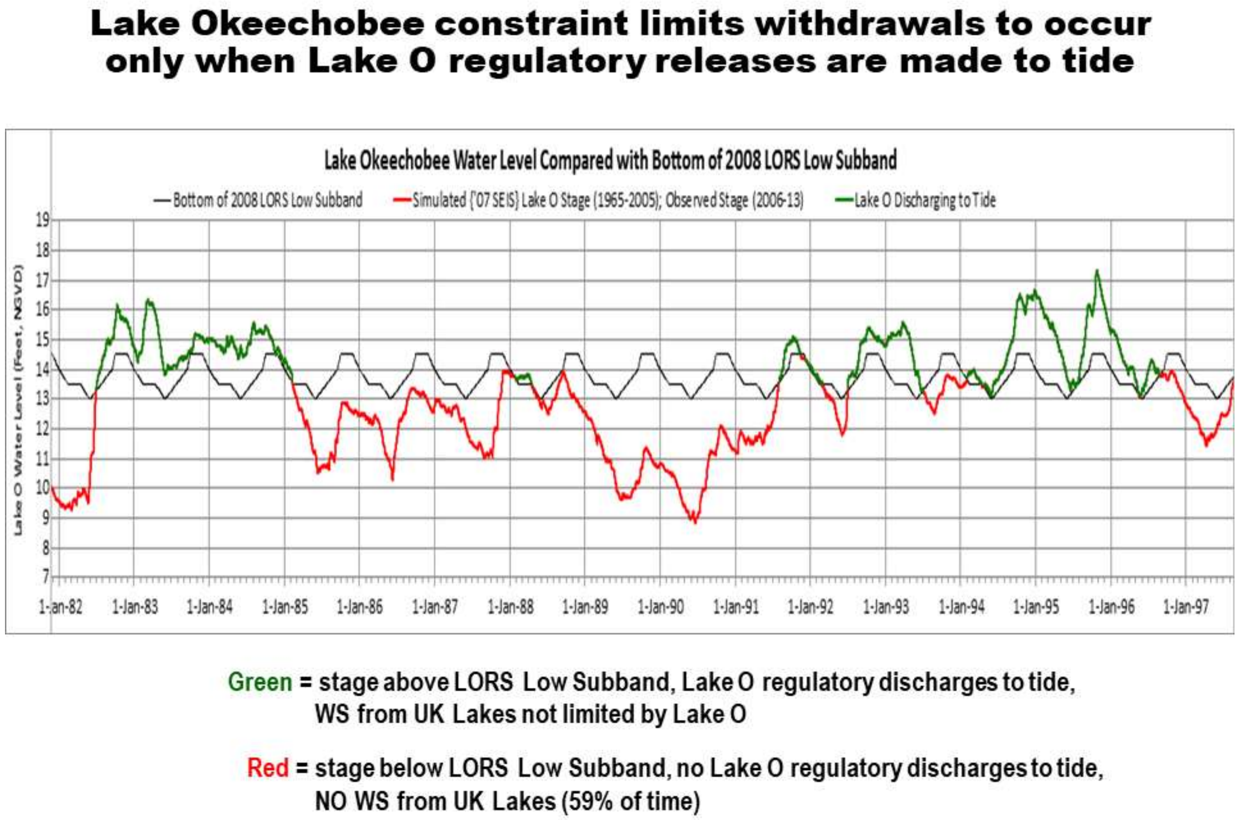


Figure 7-7. Lake Okeechobee constraint used by the UK-OPS Model.

7.2.4 Simulation Results

The UK-OPS Model simulation of the Base, WSmax, and WSmaxL scenarios revealed the effects of one possible withdrawal scenario on the draft KRCOL Water Reservation rule criteria. The outputs examined and presented here are limited to comparisons of TOH water budgets, TOH stage percentiles, S-65 annual flow, and water supply reliability.

7.2.4.1 Lake Tohopekaliga Water Budget

Figure 7-8 shows the TOH annual water budget for the WSmax and WSmaxL simulations. The water supply withdrawal component is shown for each simulation year and is small relative to the other water budget components. Note that the WSmaxL scenario has less withdrawal volume. Annual average withdrawal decreases from 39,000 acre-feet/year for WSmax to 19,000 acre-feet/year for WSMaxL, a 51% reduction that is due to the Lake Okeechobee constraint, which significantly reduces the number of days withdrawals can be made.

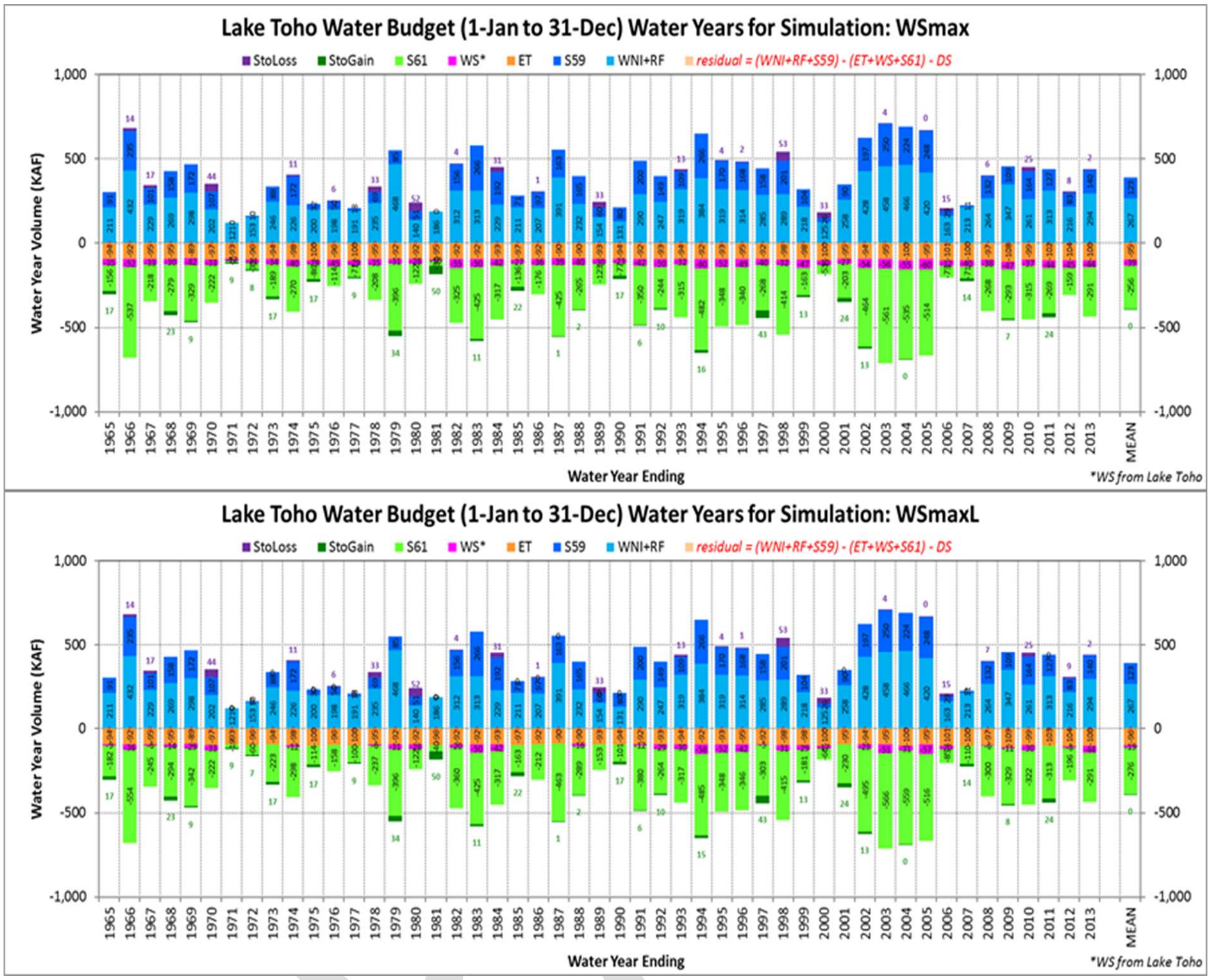


Figure 7-8. Water budget comparison of WSmax and WSmaxL for Lake Tohopekaliga.

7.2.4.2 Lake Tohopekaliga Stage Percentiles

Figure 7-9 compares the TOH stage percentiles for the three simulations (Base, WSmax, and WSmaxL). Results demonstrate a downward shift in the percentiles of the WSmax scenario (red) relative to the Base (black). The WSmaxL scenario (green) falls between the other simulations because the withdrawals are less than those of the WSmax simulation.

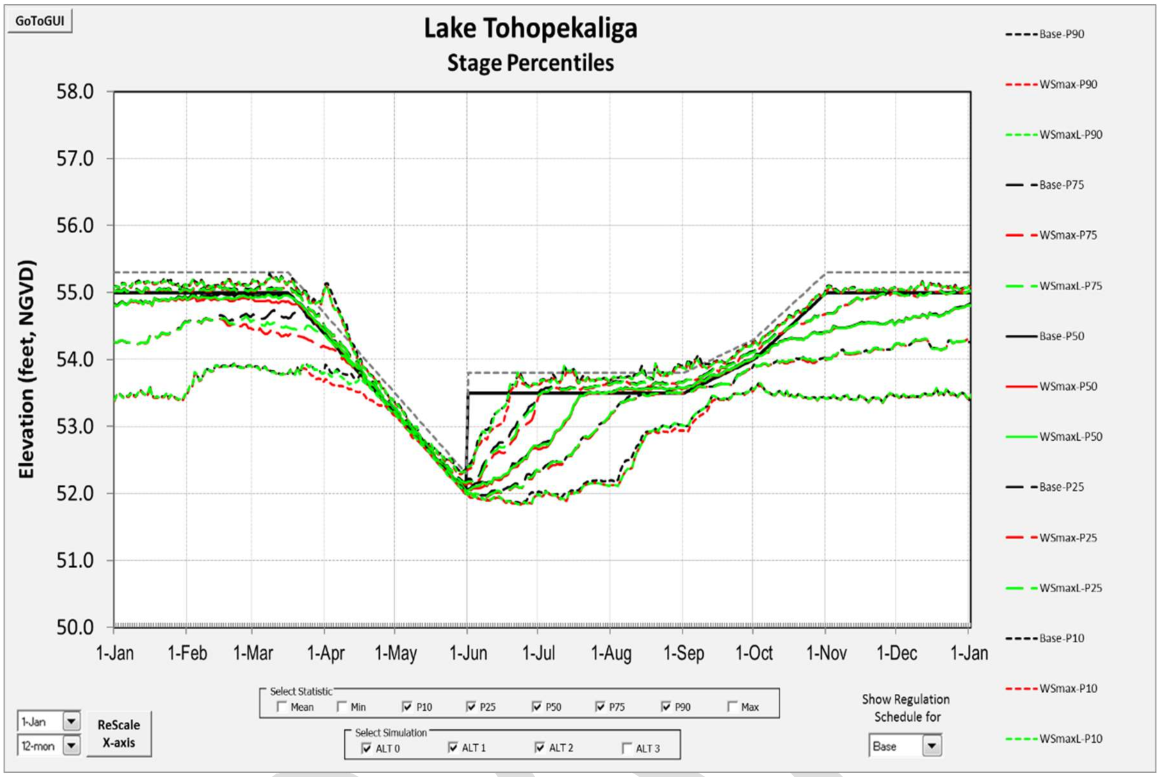


Figure 7-9. Lake Tohopekaliga stage percentiles for the Base, WSmax, and WSmaxL scenarios.

7.2.4.3 S-65 Annual Flow

A key criterion of the draft KRCOL Water Reservation rules is that the reduction in mean annual flow for the 41-year simulation period cannot exceed 5%[1]. This is a permitting criterion to evaluate proposed withdrawals. This criterion cannot be used for real-time operations to determine whether withdrawals can or cannot occur.

Figure 7-10 shows the mean annual flow for the WSmax scenario is exactly -5.0%. In fact, the max withdrawal capacity of 64 million gallons per day was determined by iteratively running the model until this limit was reached. If all future water supply withdrawals were to come from TOH, then they could not exceed a total of 64 million gallons per day. In reality, permitted withdrawals will be in various amounts and from any of the six lake systems that allow withdrawals, subject to the WRL and downstream constraints. This is one reason why the UK-OPS Model is needed as regulatory tool: to evaluate each proposed individual withdrawal in the context of the cumulative withdrawals that already have been permitted. Once the 5% limit is reached, no further withdrawals will be permitted.

[1] The 5% threshold was established from prior technical work (SFWMD 2009). The UK-OPS Model was used to determine the reduction in the mean annual flow as a result of withdrawals from a water use permit issued to Toho Water Authority (49-02549-W). This permit resulted in a 0.82% reduction in mean annual flow at S-65, thereby reducing the 5% threshold to 4.18%, which is reflected in the draft Water Reservation rules.

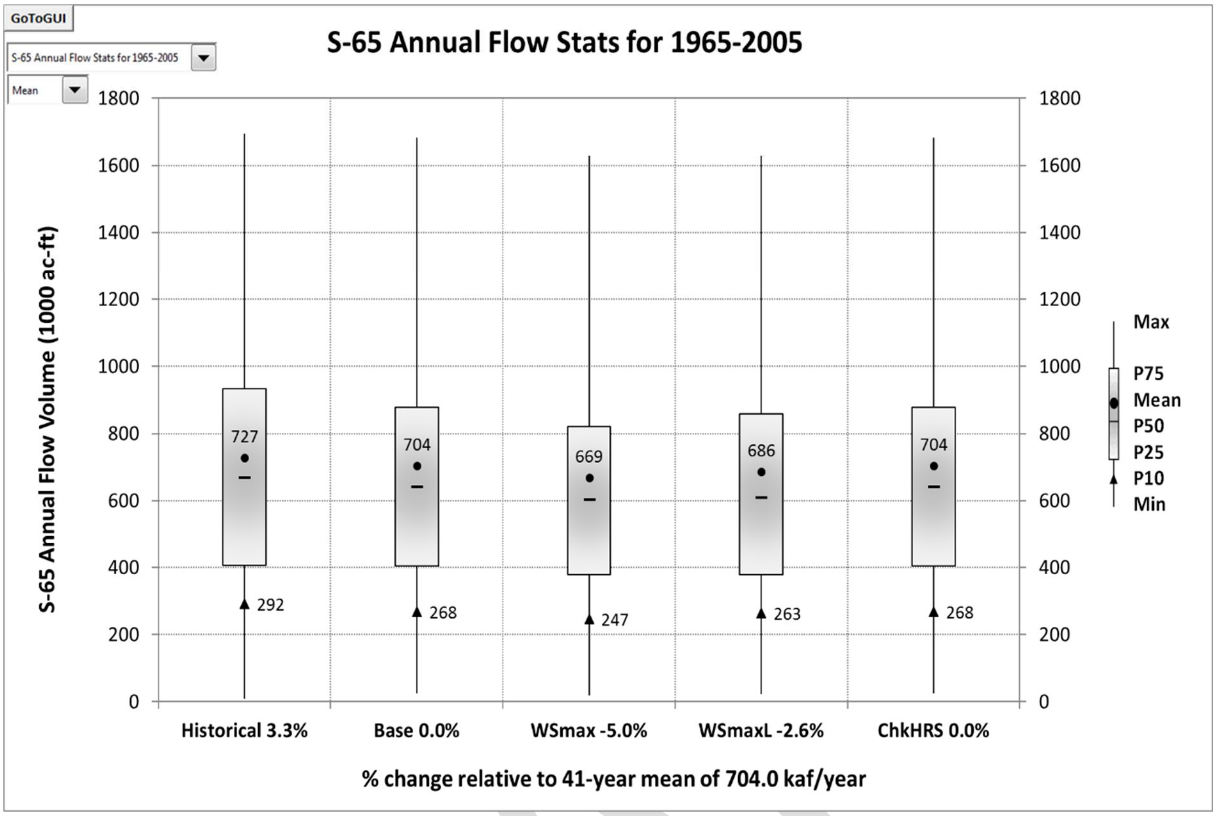


Figure 7-10. Mean annual flow at the S-65 structure under the WSmax scenario.

7.2.4.4 Water Supply Reliability

The simulated water supply reliability information for the WSmax and WSmaxL scenarios are shown in **Tables 7-1** and **7-2**, respectively. The target reliability (percent of time water supply withdrawals occur) was arbitrarily set at 70%. Users can change this target to match the level of performance desired for their particular project. The table summaries show the reliability under the WSmax scenario is 8 calendar years out of the 49 years simulated. The WSmaxL scenario has only 4 years out of the 49 years that meet or exceed the 70% reliability target. This result illustrates the impact from the Lake Okeechobee constraint. Additionally, a larger pump size can be tested to determine if supply targets can be better met. The reliability measures reflect the timing of withdrawals, but larger withdrawals could occur during the allowable days if they do not exceed the 5% cumulative limit. These scenarios can be tested with the UK-OPS Model.

Table 7-1. Lake Tohopekaliga water supply reliability for the WSmax scenario.

Lake TOH Water Supply Reliability Table for WSmax

No. of Days per Month with Lake Toho WS Withdrawals at 99.0 cfs (64.0 MGD); Percent of Time WS Withdrawal

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Days Jan-Dec	Vol(kaf) Jan-Dec	AvgMGD Jan-Dec	CalYear Jan-Dec	WetSeas May-Oct	DrySeas Nov-Apr	WatYear May-Apr
1965	0	16	31	30	31	1	9	31	8	7	0	14	178	34.96	31.21	48.8%	47.3%		
1966	23	28	31	30	31	14	31	31	30	15	0	0	264	51.85	46.29	72.3%	82.6%	74.1%	58.4%
1967	0	16	31	30	31	0	8	31	20	1	0	0	168	33.00	29.46	46.0%	49.5%	50.9%	62.7%
1968	0	0	0	25	31	26	30	31	10	0	0	0	153	30.05	26.75	41.8%	69.6%	26.3%	31.7%
1969	19	28	31	30	31	0	0	0	6	27	21	22	215	42.23	37.70	58.9%	34.8%	65.6%	64.7%
1970	31	28	31	30	31	9	0	10	0	0	0	0	170	33.39	29.81	46.6%	27.2%	91.5%	62.2%
1971	0	0	3	28	31	0	0	0	0	0	0	0	62	12.18	10.87	17.0%	16.8%	29.2%	22.2%
1972	0	0	13	30	31	0	6	23	6	0	0	0	109	21.41	19.06	29.8%	35.9%	34.7%	20.2%
1973	0	26	31	30	31	3	0	13	29	11	0	0	174	34.18	30.51	47.7%	47.3%	55.7%	41.9%
1974	0	14	31	30	31	2	30	31	30	4	0	0	203	39.87	35.59	55.6%	69.6%	50.0%	44.4%
1975	0	0	21	30	31	0	0	27	19	11	2	0	141	27.70	24.72	38.6%	47.8%	38.7%	49.0%
1976	4	29	31	30	31	19	28	29	26	2	0	0	229	44.98	40.04	62.6%	73.4%	59.6%	50.3%
1977	5	28	31	30	31	1	0	5	13	2	0	3	149	29.27	26.13	40.8%	28.3%	59.0%	62.7%
1978	19	28	31	30	31	0	6	29	3	0	0	0	177	34.77	31.04	48.5%	37.5%	67.0%	44.7%
1979	4	28	31	30	31	1	0	0	27	7	0	0	159	31.23	27.88	43.6%	35.9%	58.5%	44.4%
1980	20	29	31	30	31	3	0	0	0	0	0	0	144	28.28	25.18	39.3%	18.5%	66.2%	48.1%
1981	0	0	0	0	11	4	0	3	21	0	0	13	52	10.21	9.12	14.2%	21.2%	5.2%	9.3%
1982	25	28	31	30	31	30	31	31	28	13	0	0	278	54.60	48.74	76.2%	89.1%	74.5%	45.5%
1983	7	28	31	30	31	13	20	31	28	13	7	15	254	49.89	44.54	69.6%	73.9%	59.9%	71.2%
1984	31	29	31	30	31	3	27	30	4	0	0	0	216	42.43	37.77	59.0%	51.6%	81.7%	76.2%
1985	0	0	9	30	31	0	0	30	27	10	0	0	137	26.91	24.02	37.5%	53.3%	33.0%	36.7%
1986	30	28	31	30	31	0	0	23	12	0	0	0	185	36.34	32.44	50.7%	35.9%	70.8%	59.5%
1987	29	28	31	30	31	2	0	0	0	0	19	29	199	39.09	34.89	54.5%	17.9%	70.3%	50.4%
1988	18	29	31	30	30	0	0	12	26	0	2	28	206	40.46	36.02	56.3%	37.0%	87.3%	51.6%
1989	11	11	29	30	31	0	0	18	17	6	0	0	153	30.05	26.83	41.9%	39.1%	67.0%	49.0%
1990	0	5	31	30	31	0	0	20	0	0	0	0	117	22.98	20.51	32.1%	27.7%	45.8%	37.8%
1991	0	2	29	30	31	30	31	31	13	16	0	0	213	41.84	37.35	58.4%	82.6%	43.4%	30.7%
1992	0	22	31	30	31	13	20	27	29	19	6	27	255	50.09	44.59	69.7%	75.5%	53.5%	64.2%
1993	29	28	31	30	31	5	0	0	10	0	0	0	164	32.21	28.76	44.9%	25.0%	85.8%	79.5%
1994	2	28	31	30	31	23	25	31	30	16	28	31	306	60.10	53.65	83.8%	84.8%	57.5%	37.5%
1995	30	28	31	30	31	0	5	31	27	28	13	10	264	51.85	46.29	72.3%	66.3%	98.6%	91.5%
1996	30	29	31	30	31	30	23	21	19	5	0	0	249	48.91	43.54	68.0%	70.1%	81.7%	72.4%
1997	7	28	31	30	31	4	12	29	5	0	1	28	206	40.46	36.12	56.4%	44.0%	59.9%	61.6%
1998	31	28	31	30	31	2	0	0	5	3	0	0	161	31.62	28.23	44.1%	22.3%	84.9%	63.0%
1999	0	26	31	30	31	1	13	27	14	30	26	12	241	47.34	42.26	66.0%	63.0%	55.7%	35.1%
2000	18	29	31	30	31	0	0	9	7	0	0	0	155	30.45	27.10	42.3%	25.5%	83.1%	71.6%
2001	0	0	0	26	31	3	16	27	30	5	0	0	138	27.11	24.20	37.8%	60.9%	26.9%	20.0%
2002	0	24	31	30	31	22	31	31	30	3	12	28	273	53.62	47.87	74.8%	80.4%	54.7%	54.0%
2003	31	28	31	30	31	25	31	31	21	8	2	16	285	55.98	49.97	78.1%	79.9%	90.1%	84.4%
2004	21	29	31	30	31	0	12	29	30	31	26	12	282	55.39	49.31	77.0%	72.3%	75.1%	75.4%
2005	30	28	31	30	31	30	29	31	9	7	27	21	304	59.71	53.30	83.3%	74.5%	88.7%	79.5%
2006	10	28	31	30	31	0	2	12	21	0	0	0	165	32.41	28.93	45.2%	35.9%	84.0%	77.8%
2007	0	26	31	30	31	20	21	20	14	8	0	1	202	39.68	35.42	55.3%	62.0%	55.7%	41.9%
2008	10	29	31	30	31	0	8	30	23	4	0	0	196	38.50	34.27	53.6%	52.2%	62.0%	58.7%
2009	0	19	31	30	31	30	31	31	25	1	0	11	240	47.14	42.08	65.8%	81.0%	52.4%	48.2%
2010	16	28	31	30	31	30	19	2	0	0	0	0	187	36.73	32.79	51.2%	44.6%	69.3%	72.6%
2011	0	20	31	30	31	0	9	31	25	26	20	3	226	44.39	39.63	61.9%	66.3%	52.8%	44.7%
2012	4	27	31	30	31	6	28	29	29	13	0	0	228	44.78	39.87	62.3%	73.9%	68.5%	64.8%
2013	0	14	31	30	31	25	31	31	28	3	0	0	224	44.00	39.28	61.4%	81.0%	50.0%	57.8%
MEANS																			
48YR	11	21	27	29	31	9	13	21	17	7	4	7	197	38.71	34.53	54.0%	52.9%	61.5%	54.0%
41YR	12	21	27	29	30	8	12	21	16	7	5	8	195	38.27	34.14	53.4%	51.1%	61.9%	53.4%

SUMMARY STATISTICS	CalYear	WetSeas	DrySeas	WatYear
No. of years used for stats	49	49	48	48
Years used for stats	'65-'13	'65-'13	'66-'13	'66-'13
# Yrs with WS duration > 70%	8	15	16	11
Annual Exceedance Frequency	16.3%	30.6%	33.3%	22.9%
Return Period (1-in-Nyrs)	6.1	3.3	3.0	4.4

Table 7-2. Lake Tohopekaliga water supply reliability for the WSmaxL scenario.

Lake TOH Water Supply Reliability Table for WSmaxL																Percent of Time WS Withdrawal			
	No. of Days per Month with Lake Toho WS Withdrawals at 99.0 cfs (64.0 MGD)												Days	Vol(kaf)	AvgMGD	CalYear	WetSeas	DrySeas	WatYear
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	May-Oct	Nov-Apr	May-Apr
1965	0	16	29	0	0	0	0	0	0	0	0	0	45	8.84	7.89	12.3%	0.0%		
1966	1	28	30	11	0	4	31	31	30	15	0	0	181	35.55	31.74	49.6%	60.3%	33.0%	19.2%
1967	0	16	15	0	0	0	0	0	0	0	0	0	31	6.09	5.44	8.5%	0.0%	14.6%	38.9%
1968	0	0	0	0	0	2	30	31	10	0	0	0	73	14.34	12.76	19.9%	39.7%	0.0%	0.0%
1969	0	0	22	26	22	0	0	0	6	27	21	22	146	28.68	25.60	40.0%	29.9%	33.0%	33.2%
1970	31	28	31	30	31	9	0	10	0	0	0	0	170	33.39	29.81	46.6%	27.2%	91.5%	59.7%
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	13.7%
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1974	0	0	0	0	0	0	0	29	30	4	0	0	63	12.37	11.05	17.3%	34.2%	0.0%	0.0%
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	17.3%
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1978	0	0	0	0	0	0	0	29	3	0	0	0	32	6.29	5.61	8.8%	17.4%	0.0%	0.0%
1979	4	28	31	30	31	1	0	0	27	7	0	0	159	31.23	27.88	43.6%	35.9%	58.5%	34.2%
1980	20	29	31	30	31	3	0	0	0	0	0	0	144	28.28	25.18	39.3%	18.5%	66.2%	48.1%
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	9.3%
1982	0	0	0	0	0	1	31	31	28	13	0	0	104	20.43	18.24	28.5%	56.5%	0.0%	0.0%
1983	7	28	31	30	31	13	20	31	28	13	7	15	254	49.89	44.54	69.6%	73.9%	59.9%	54.8%
1984	31	29	31	30	31	3	27	30	4	0	0	0	216	42.43	37.77	59.0%	51.6%	81.7%	76.2%
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	26.0%
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1988	5	28	31	16	0	0	0	0	0	0	0	0	80	15.71	13.99	21.9%	0.0%	37.6%	21.9%
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1991	0	0	0	0	0	0	0	30	13	16	0	0	59	11.59	10.35	16.2%	32.1%	0.0%	0.0%
1992	0	20	0	0	0	0	22	27	29	19	6	27	150	29.46	26.23	41.0%	52.7%	9.4%	21.6%
1993	29	28	31	30	31	5	0	0	0	0	0	0	154	30.25	27.00	42.2%	19.6%	85.8%	67.9%
1994	1	28	31	20	31	23	25	31	30	16	28	31	295	57.94	51.73	80.8%	84.8%	52.4%	31.8%
1995	30	28	31	30	31	0	5	31	27	28	13	10	264	51.85	46.29	72.3%	66.3%	98.6%	91.5%
1996	30	29	31	30	24	30	23	16	0	0	0	0	213	41.84	37.25	58.2%	50.5%	78.4%	72.4%
1997	0	0	0	0	0	0	0	0	2	0	0	21	23	4.52	4.03	6.3%	1.1%	0.0%	25.5%
1998	31	28	31	30	31	2	0	0	1	4	0	0	158	31.03	27.70	43.3%	20.7%	81.1%	39.2%
1999	0	26	26	0	0	0	8	7	14	30	26	12	149	29.27	26.13	40.8%	32.1%	24.5%	24.7%
2000	18	29	31	10	0	0	0	0	0	0	0	0	88	17.28	15.39	24.0%	0.0%	59.2%	50.5%
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
2002	0	25	2	0	0	0	7	31	30	3	0	21	119	23.37	20.87	32.6%	38.6%	12.7%	7.4%
2003	31	28	31	22	12	27	31	31	21	8	2	16	260	51.07	45.59	71.2%	70.7%	68.4%	55.9%
2004	21	29	23	0	0	0	0	0	16	31	26	12	158	31.03	27.63	43.2%	25.5%	42.7%	60.4%
2005	30	25	31	30	22	30	29	31	9	7	27	21	292	57.35	51.20	80.0%	69.6%	83.0%	55.1%
2006	10	28	31	30	4	0	0	0	0	0	0	0	103	20.23	18.06	28.2%	2.2%	71.2%	75.3%
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	1.1%
2008	0	0	0	0	0	0	0	4	23	4	0	0	31	6.09	5.42	8.5%	16.8%	0.0%	0.0%
2009	0	0	0	0	0	0	0	31	25	1	0	0	57	11.20	9.99	15.6%	31.0%	0.0%	8.5%
2010	0	11	31	30	31	30	19	2	0	0	0	0	154	30.25	27.00	42.2%	44.6%	48.6%	35.3%
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	22.5%
2012	0	0	0	0	0	0	0	0	29	13	0	0	42	8.25	7.34	11.5%	22.8%	0.0%	0.0%
2013	0	14	31	30	31	25	31	31	28	3	0	0	224	44.00	39.28	61.4%	81.0%	50.0%	32.1%
MEANS																			
48YR	7	12	14	10	9	4	7	11	9	5	3	4	96	18.80	16.77	26.2%	24.6%	27.9%	26.2%
41YR	8	13	14	10	9	4	7	11	9	6	4	5	100	19.55	17.44	27.3%	24.6%	29.7%	27.3%

SUMMARY STATISTICS	CalYear	WetSeas	DrySeas	WatYear
No. of years used for stats	49	49	48	48
Years used for stats	'65-'13	'65-'13	'66-'13	'66-'13
# Yrs with WS duration > 70%	4	4	8	4
Annual Exceedance Frequency	8.2%	8.2%	16.7%	8.3%
Return Period (1-in-Nyrs)	12.3	12.3	6.0	12.0

8 SUMMARY AND RECOMMENDATIONS

This section summarizes the strengths and limitations of the UK-OPS Model and suggests future enhancements to improve model accuracy and utility. The UK-OPS Model uses a simple water balance approach to simulate water levels and discharges for the primary hydrologic components of the larger lake systems in the UKB. The model was developed to quickly test alternative operating strategies for KCH, TOH, and ETO specifically. It was later modified to serve as a water use permit evaluation tool to assess the effects of proposed water supply withdrawals, subject to the draft KRCOL Water Reservation rule criteria. Original model development was done expeditiously; user-friendly interfaces and documentation beyond comments within the worksheets were not included in the initial development effort. The need to document and peer review the UK-OPS Model arose during the planning phase of the draft KRCOL Water Reservation rules.

This report describes the purpose, utility, and technical details of the UK-OPS Model. The report is not a users' guide, but it is prerequisite reading for analysts who want to use the model. Included in this report are details on model structure, inputs and outputs, and model validation. Two applications of the UK-OPS Model were described in this report: 1) seasonal operations planning, including the SFWMD's monthly position analysis; and 2) testing the effects of hypothetical surface water withdrawals on the draft KRCOL Water Reservation rule criteria. These applications illustrate appropriate uses of the UK-OPS Model.

Strengths of the UK-OPS Model include the ability to rapidly test alternative operating ideas (i.e., run time of 4 minutes versus days or even weeks for more detailed models), ease of use in a readily available environment (i.e., Microsoft Excel®), broad range of options for specifying alternative operations, immediate updating of the outputs and performance metrics, and flexibility to modify the Microsoft Excel® worksheets to add additional features and/or performance summary graphics.

Model users have made the following comments regarding the usefulness of the UK-OPS Model:

- Key strengths of the UK-OPS Model are its quick simulation time and ability to immediately visualize outputs.
- Time-series plots provide a useful way to visualize and confirm the input operations are being correctly simulated.
- Water budgets are a helpful way to quickly confirm mass is conserved.
- The S-65 mean annual discharge and water supply reliability summaries enable rapid assessment of the effects of proposed water supply withdrawals on the draft KRCOL Water Reservation rule criteria.

Limitations of the UK-OPS Model include the potential need for routing computations for the small lakes, lack of extensive documentation within the workbook, and dependence on another model or historical data to generate the boundary inflows.

There are several areas where the UK-OPS Model may be exploited by more users with varying levels of expertise in water management, hydrology, and hydraulics. Some initial recommendations are listed below, and additional recommendations are expected based on input from internal and external peer reviewers.

1. Extend the simulation period by updating the inputs using available historical data and/or outputs from detailed regional hydrologic models.
2. Simplify the effort required to perform simulation period extensions by leveraging additional Microsoft Excel® features (e.g., making range names more dynamic).

3. Improve the GUI of the UK-OPS Model to appeal to more users and enable better utility of the model.
4. Expand the instructions for users within the model. Online documentation and built-in tutorials would greatly enhance usability of the model.

LITERATURE CITED

AECOM. 2010. *KB Modeling and Operations Study, Final KBMOS Daily Planning Tool Testing Plan, AFET-LT and AFET FLOOD Concurrent Calibration Process and Criteria*. Prepared for South Florida Water Management District, West Palm Beach, FL.

Fan, A. 1986. *A Routing Model for the Upper Kissimmee Chain of Lakes*. SFWMD TP86-5. South Florida Water Management District, West Palm Beach, FL.

Hirsch, R.M. 1978. *Risk Analysis for a Water-Supply System – Occoquan Reservoir, Fairfax and Prince William counties, Virginia*. Hydrologic Science Bulletin 23(4):476-505.

SFWMD. 2005. *Documentation of the South Florida Water Management Model Version 5.5*. South Florida Water Management District, West Palm Beach, FL. November 2005. 325 pp.

SFWMD. 2009. *Alternative Formulation Evaluation Tool (AFET) Model Documentation/Calibration Report for the Kissimmee Basin Modeling and Operations Study (KBMOS)*. Prepared by AECOM and DHI for the South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2017. *Kissimmee Basin H&H Models Report*. Hydrology and Hydraulics Bureau, South Florida Water Management District, West Palm Beach, FL. December 2017.

USACE. 1996. *Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement*. United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL. January 1996.

USACE. 2019. *East Lake Tohopekaliga Drawdown and Habitat Enhancement – Final Environmental Impact Statement*. Prepared by South Florida Engineering and Consulting LLC, West Palm Beach, FL. Prepared for United States Army Corps of Engineers, Jacksonville District, Cocoa Permit Section, Cocoa, FL. July 2019.

VanZee, R. 2011. *Regional Simulation Model – Basins (RSMBN) Documentation and User Manual*. Hydrologic and Environmental Systems Modeling. South Florida Water Management District, West Palm Beach, FL. March 28, 2011. 61 pp.

ATTACHMENT

SAMPLE EMAIL COMMUNICATION OF AUGUST 2019
UK-OPS POSITION ANALYSIS

From: Neidrauer, Calvin
Sent: Thursday, August 01, 2019 5:42 PM
To: Morancy, Danielle <dmorancy@sfwmd.gov>
Cc: Wilcox, Walter <wwilcox@sfwmd.gov>; Barnes, Jenifer <jabarne@sfwmd.gov>; Bousquin, Steve <sbousqu@sfwmd.gov>; Glenn, Lawrence <lglenn@sfwmd.gov>; Kirkland, Suelynn <skirklan@sfwmd.gov>; Anderson, H. David <dander@sfwmd.gov>; Mohottige, Dillan <dmohotti@sfwmd.gov>; Godin, Jason <jgodin@sfwmd.gov>
Subject: August PA UK-OPS Simulation Assumptions

FYI:

The UK-OPS Model simulation for the August PA was completed today (01-August). Operations assumptions for Lake KCH changed from the June PA, and were informed by the 2019 wet season discharge plan developed by the SFWMD with input from the USFWS & FFWCC. Assumptions for TOH & ETO were consistent with last month; the spring fish & wildlife (F&W) recessions are assumed to start on 15-Jan-2019 at 0.4 feet below the regulation schedules.

Results are to be used as input to the corresponding SFWMM simulation. A copy of the Excel workbook is available in the following server folder:

\\ad.sfwmd.gov\dfsroot\data\hesm_pa\PA_BASE_DIR\PA\UK-OPSmodel\

Filename = UK-OPS(v3.12)_2019AugPA.xlsm

Use the **ALT2** simulation output (Run name = **AugPA**).

The simulated stages and flows are in the **ALT2 worksheet tab**.

Initial (31-July) Conditions:

E. Lake Toho: 56.29 feet, NGVD (TOHOEE+)

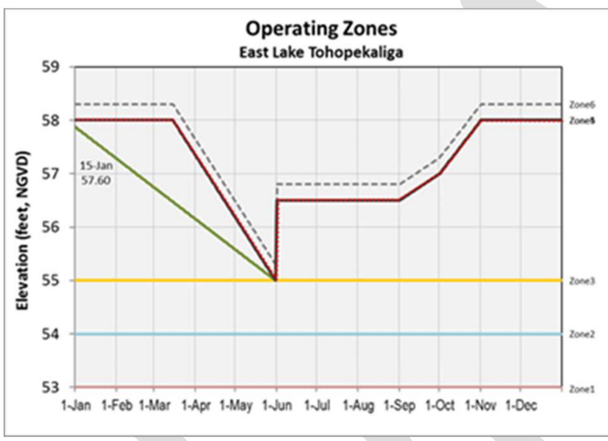
Lake Toho: 53.48 feet, NGVD (LTOHOW AVG)

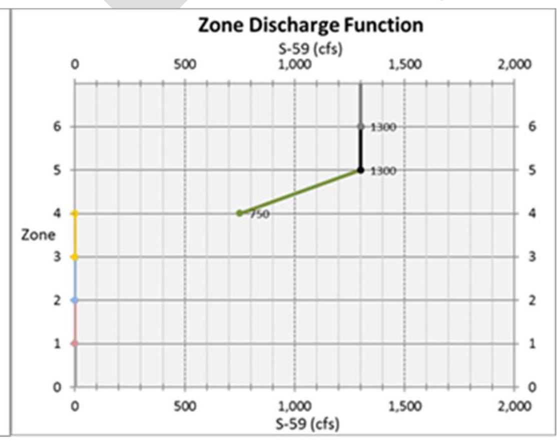
Lake KCH: 50.20 feet, NGVD (LKISS AVG)

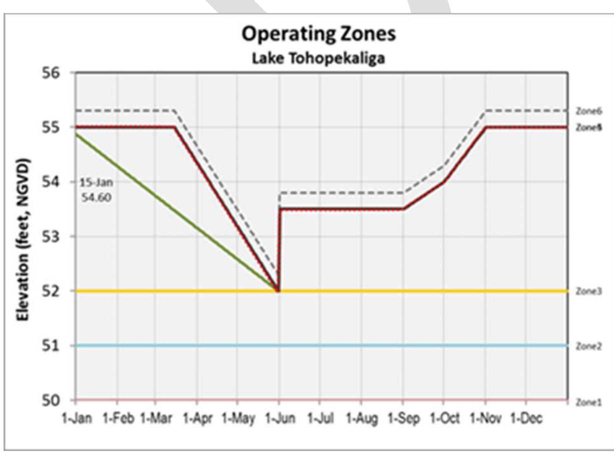
For the August 2019 Position Analysis the Upper Kissimmee Operations Screening (UK-OPS) Model was used to simulate water levels and releases from Lakes Kissimmee-Cypress-Hatchineha, Tohopekaliga, and East Lake Tohopekaliga. The UK-OPS Model assumptions for operations are listed below. Details regarding model version features are listed at the end of this e-mail.

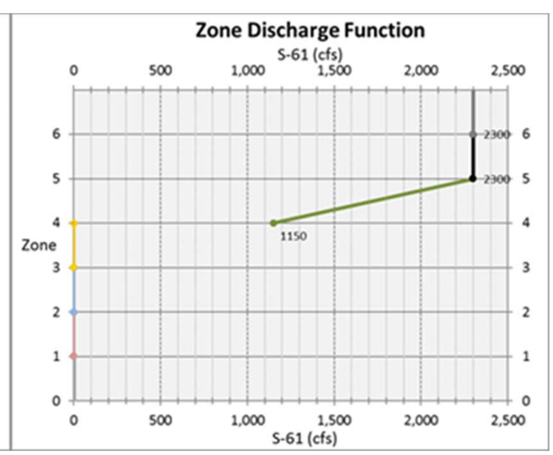
UK-OPS Model assumptions for the August-2019 PA:

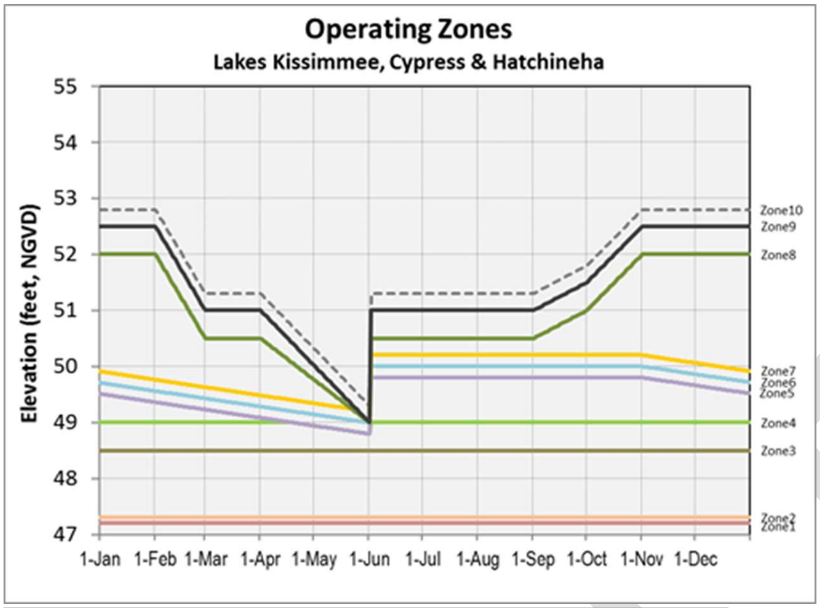
1. Hydrology (lake inflows) based on historical/observed stage and flow data from DBHYDRO (same assumption since Jan 2016).
2. Regulation of Lakes Toho and East Lake Toho according to the standard Regulation Schedules with spring recession operations approximated as shown below. Recession ops start 15-Jan. Note the red dotted lines represent the standard regulation schedule Zone A line.
3. Regulation of Lakes Kissimmee, Cypress and Hatch according to 2019 wet season operations designed to achieve desired river flows and lake stage recession rates. See graphic of discharge plan below. Rate of change limits for S-65A flows shown below were set in May 2019. The rate of change limits apply for stages below Zone A of the KCH schedule.
4. Starting with the Nov-2017 PA, KCH simulated outflows were measured at S-65A. So S-65 releases are made with consideration of Pool A runoff contribution to S-65A.



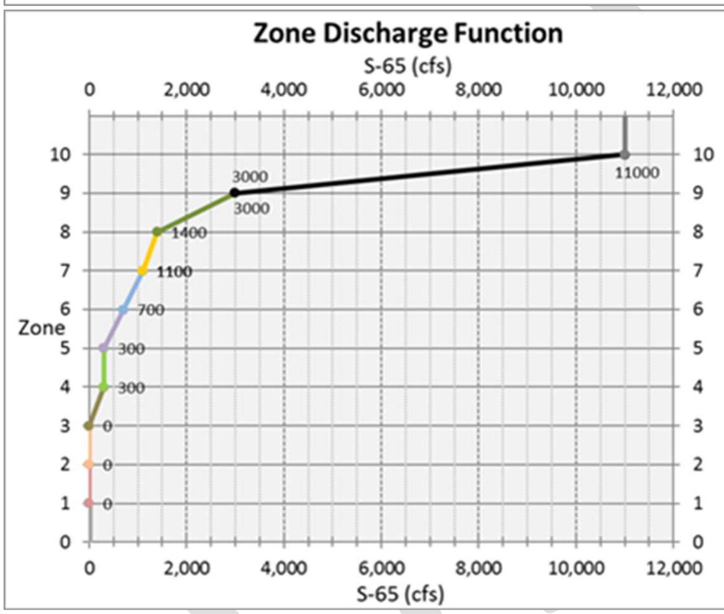




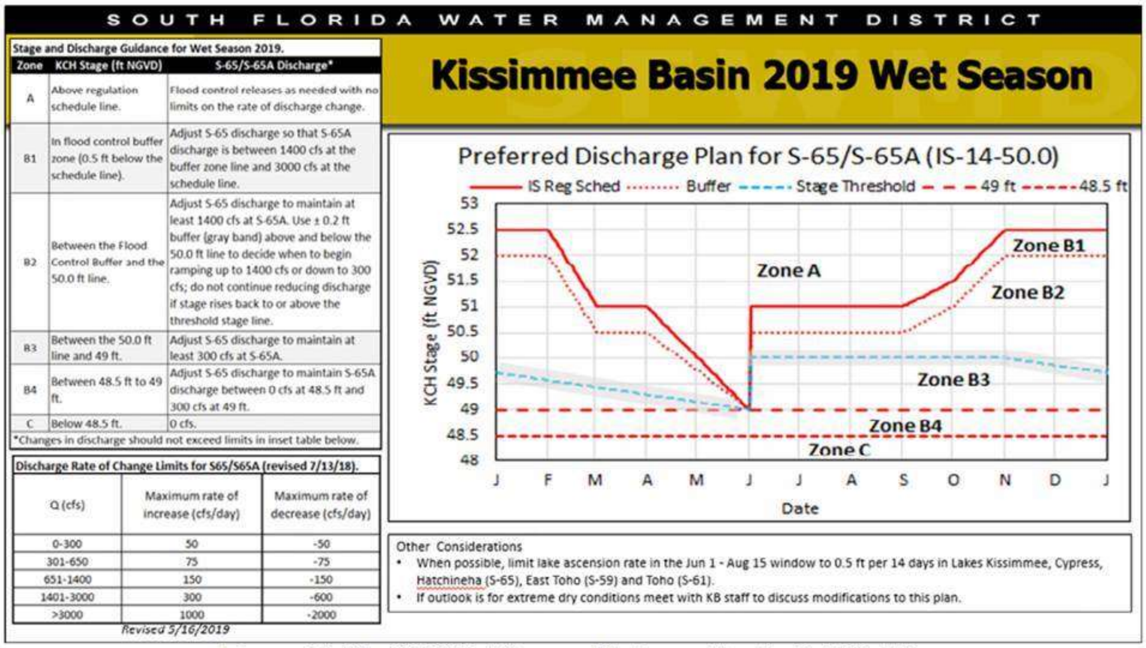



Operating Zones
Lakes Kissimmee, Cypress & Hatchineha
Elevation (feet, NGVD)
55
54
53
52
51
50
49
48
47
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Zone10
Zone9
Zone8
Zone7
Zone6
Zone5
Zone4
Zone3
Zone2
Zone1

4271


Zone Discharge Function
S-65 (cfs)
0
2,000
4,000
6,000
8,000
10,000
12,000
Zone
10
9
8
7
6
5
4
3
2
1
0
3000
3000
11000
1400
1100
700
300
300
0
0
0
S-65 (cfs)

4272



Stage and Discharge Guidance for Wet Season 2019.

Zone	KCH Stage (ft NGVD)	S-65/S-65A Discharge*
A	Above regulation schedule line.	Flood control releases as needed with no limits on the rate of discharge change.
B1	In flood control buffer zone (0.5 ft below the schedule line).	Adjust S-65 discharge so that S-65A discharge is between 1400 cfs at the buffer zone line and 3000 cfs at the schedule line.
B2	Between the Flood Control Buffer and the 50.0 ft line.	Adjust S-65 discharge to maintain at least 1400 cfs at S-65A. Use ± 0.2 ft buffer (gray band) above and below the 50.0 ft line to decide when to begin ramping up to 1400 cfs or down to 300 cfs; do not continue reducing discharge if stage rises back to or above the threshold stage line.
B3	Between the 50.0 ft line and 49 ft.	Adjust S-65 discharge to maintain at least 300 cfs at S-65A.
B4	Between 48.5 ft to 49 ft.	Adjust S-65 discharge to maintain S-65A discharge between 0 cfs at 48.5 ft and 300 cfs at 49 ft.
C	Below 48.5 ft.	0 cfs.

*Changes in discharge should not exceed limits in inset table below.

Discharge Rate of Change Limits for S65/S65A (revised 7/13/18).

Q (cfs)	Maximum rate of increase (cfs/day)	Maximum rate of decrease (cfs/day)
0-300	50	-50
301-650	75	-75
651-1400	150	-150
1401-3000	300	-600
>3000	1000	-2000

Figure 11. The 2019 Wet Season Discharge Plan for S-65/S-65A.

UK-OPS Model Version notes:

The November, 2015 investigation of the UKISS Model output (2007 version) indicated a significant underestimation of S-65 flows for the 1997-98 very wet period. So while SFWMD H&H Bureau staff efforts continue toward improving the modeling tools for the Kissimmee basins, the intermediate solution is to continue to use the UK-OPS Model with the lateral lake inflows computed using observed data.

Version 3.12 of the UK-OPS Model was used beginning with the July 2019 PA. V3.12 includes features to allow testing alternative operations and water reservation lines. These features are not used for the current PA simulations.

Version 3.10 of the UK-OPS Model was used beginning with the January 2019 PA. Version 3.10 includes options to simulate lake stage recession operations for lakes KCH, TOH, and ETO. The new logic determines daily releases necessary to achieve a user-specified stage recession rate. Options for KCH include constraining the S-65 release rates-of-change by the user-specified release rate limits. See the Notes page and comments in the routing worksheets for more detail. These changes are not used for current PA simulations.

Version 3.07 of the UK-OPS Model was used beginning with the March 2018 PA. Version 3.07 includes new features to enable testing alternative strategies for the Kissimmee Reservation, particularly a water reservation line for Lakes KCH (to limit upstream withdrawals). Other changes include separation of the WRL zone specification from the regulation schedules. See the Notes tab for further detail. These changes do not affect the position analysis simulations.

Version 3.05 of the UK-OPS Model was used beginning with the March 2017 PA. Version 3.05 includes additional capability to view individual year stage and discharge hydrographs for the three primary lake systems (KCH, TOH, and ETO). Use the buttons in the 5th column of the PM & Indicator buttons to access the new hydrographs. Thanks to Naiming Wang for this addition to the model.

Cal

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APPENDIX D: PEER-REVIEW REPORTS FOR THE UK-OPS MODEL

APPENDIX E:
2009 PEER-REVIEW REPORT

APPENDIX F: ADDITIONAL FLORAL AND FAUNAL COMMUNITIES IN THE KISSIMMEE RIVER AND FLOODPLAIN

PLANT COMMUNITIES

A major component of fish and wildlife habitat is vegetation. Floodplain wetlands are crucial breeding and foraging areas for fish and wildlife (Scheaffer and Nickum 1986, Gladden and Smock 1990). Plants provide food (both directly and indirectly as habitat for prey species); nesting substrate and materials; and shelter for juvenile and adult fish, birds, invertebrates, reptiles, and amphibians. Use of the Kissimmee River and its floodplain by animals is strongly linked to hydrology via vegetation. Floodplain vegetation can serve as a surrogate for the relationships between hydrology and fish and wildlife. For these reasons, and because of its prominence in the fish and wildlife discussions that follow, major classes of floodplain vegetation and their hydrologic requirements are presented first in this appendix.

General categories of Kissimmee River floodplain vegetation are described in the Kissimmee River Vegetation Classification (Bousquin and Carnal 2005). Of primary interest are the Wet Prairie, Broadleaf Marsh, and Wetland Shrub groups. These three wetland types historically (pre-channelization) accounted for more than 80% of the total floodplain habitat. Contribution by wetland group included Broadleaf Marsh at 52%, Wet Prairie at 29%, and Wetland Shrub at 1% (Spencer and Bousquin 2014). Other vegetation groups include Wetland Forest, Miscellaneous Wetlands, and Aquatic Vegetation, which are presented in more detail in Carnal and Bousquin (2005) and Bousquin and Carnal (2005).

This appendix focuses on the three dominant vegetation groups because of their prominence on the floodplain, utility as indicators of floodplain hydrologic conditions, importance to fish and wildlife in the Kissimmee River and floodplain, and the use of the Broadleaf Marsh and Wet Prairie groups as performance measures in the Kissimmee River Restoration Evaluation Program.

Broadleaf Marsh Group

The Broadleaf Marsh group is similar to numerous vegetation types described elsewhere in literature under different regional names (**Table F-1**). The Broadleaf Marsh group in the Kissimmee River floodplain is dominated by one or two indicator species, pickerelweed (*Pontederia cordata*) and/or bulltongue arrowhead (*Sagittaria lancifolia*). Prominent associated species may include the shrub buttonbush (*Cephalanthus occidentalis*) and the grass maidencane (*Panicum hemitomon*). Under normal hydrologic conditions, this community occur in standing water for much of the year. This typically results in a low complement of understory species, which may include cutgrass (*Leersia hexandra*), cupscale (*Sacciolepis striata*), alligatorweed (*Alternanthera philoxeroides*), spatterdock (*Nuphar lutea*), smartweed (*Polygonum punctatum*), bacopa (*Bacopa caroliniana*), dollarweed (*Hydrocotyle umbellata*), and the invasive shrub primrose willow (*Ludwigia peruviana*).

The Broadleaf Marsh group requires extended periods of inundation, with estimates ranging from 190 to 270 days per year (**Table F-1**, **Figure F-1**). In a study of the Kissimmee River Demonstration Project, Toth (1991) estimated broadleaf marsh hydroperiods to range from 210 to 270 days per year. Kushlan (1990) estimated depth requirements of similar marshes ranging from 0.3 to 1.0 meters (m). Wetzel (2001) estimated 0.2 to 0.4 m as the minimum depth for optimal growth rates for numerous marsh types, including several types of wet prairie. Seasonal or periodic water level reduction is also important in these communities (Kushlan 1990, United States National Vegetation Classification System 2008) to avoid exceeding the upper tolerance of the dominant species, which can uproot and die (Kushlan 1990). In general, floodplain marshes may require fires at least once per decade to inhibit woody plant invasion

(Duever 1990, Florida Natural Areas Inventory 1990, Kushlan 1990). However, the role of fire on the pre-channelization floodplain has been disputed (Toth et al. 1995).

In the pre-channelization system, communities in the Broadleaf Marsh group occurred in a broad swath that dominated the central floodplain where hydroperiods were longest and water was deepest (**Figure F-2**). Broadleaf marsh communities in 1954 (pre-channelization) accounted for approximately 52% of floodplain vegetation within the Kissimmee River Restoration Project (KRRP) Phase I construction area (most of Pool C and a portion of Pool B) (Spencer and Bousquin 2014). A few years after completion of the C-38 Canal in 1971, the Broadleaf Marsh group coverage declined to only 3.1% of the vegetation in the Phase I area. Although coverage of the Broadleaf Marsh group increased over the next 25 years to 15% in 1996, it occurred mostly in impounded wetlands (Spencer and Bousquin 2014) and its coverage remained much lower than the pre-channelized condition. This decline of long hydroperiod floodplain vegetation coincided with reductions in fish and wildlife populations over the same periods, as described elsewhere in this appendix and in Toth (1993) and Bousquin et al. (2005). The most recent KRRP Phase I floodplain vegetation map at this writing was completed in 2011, 10 years after completion of restoration construction and implementation of an interim water regulation schedule. While sporadic inundation re-established various kinds of wetland vegetation over much of the floodplain, the Broadleaf Marsh group accounted for only 21% of the Phase I area (L. Spencer, South Florida Water Management District [SFWMD], unpublished data), with most of its former distribution occupied by communities in the Wet Prairie group. Thus, while intermittent inundation has been achieved since completion of Phase I, annual durations of inundation have proved inadequate for recovery of the Broadleaf Marsh group. Expansion to its former floodplain distribution is expected when extended hydroperiods are re-established under the Headwaters Revitalization Water Regulation Schedule (United States Army Corps of Engineers 1996), currently projected for implementation in 2020.

Table F-1. Duration and depth of inundation for wetland plant communities similar to the Broadleaf Marsh and Wet Prairie groups on the Kissimmee River.

Community	Source Nomenclature	Dominant Species	Source	Duration (days)	Depth
Pickerelweed marsh	Pickerelweed Tropical Herbaceous Vegetation, Unique ID CEGL004261	Pickerelweed	USNVC (2008)	Most of year, with little variation in hydroperiod	
Floodplain marsh	Floodplain marsh, river marsh	Maidencane, buttonbush, and sawgrass; other typical plants include arrowheads and pickerelweed	FNAI (1990)	>250	
Broadleaf marsh	Broadleaf marsh	Pickerelweed and arrowhead	Toth et al. (1998)	210 to 270	
Maidencane-dominated marsh	Maidencane – Pickerelweed Herbaceous Vegetation, Unique ID CEGL004461 (Maidencane is dominant)	Maidencane	USNVC (2008)	>200	0.3-1 m
Flag marsh	Flag marshes	Includes marshes dominated by maidencane, pickerelweed, arrowhead, bulrush, beakrush, and spikerush	Kushlan (1990)	>200	0.3-1 m
Maidencane (species estimate)	Species estimate	Maidencane	Lowe (1986, Figure 5)	270 to 350	
Maidencane marsh	Maidencane Tropical Herbaceous Vegetation, Unique ID CEGL003980	Maidencane	USNVC (2008)	180 to 330	
Northern Everglades wet prairie; maidencane can be dominant	Wet prairie (northern Everglades)	Maidencane, spikerush, or beakrush	Richardson (2000)	180 to 300	Standing water
Maidencane marsh	Maidencane marsh	Maidencane	Wetzel (2001) citing Schomer and Drew (1982, page 117)	180 to 270	
Marsh	Marsh	Not specified	Duever (1990), Figure 2	114 to 264	
Southern Everglades wet prairie	Wet prairie (southern Everglades)	Not specified	Richardson (2000) citing Davis (1943)	90 to 210	Less than sloughs but deeper than sawgrass
Wet prairie	Wet prairie	Not specified	Duever et al. (1978) (wet prairie)	111 to 155	
Wet prairie	Wet prairie	Not specified	Duever (1990, Figure 2)	64 to 114	
Flatwoods wet prairie	Wet prairie (flatwoods)	Grasses, sedges, and forbs, including maidencane, cordgrass, beakrush, and muhly	Kushlan (1990)	50 to 100	
Flatwoods wet prairie	Wet prairie (flatwoods)	Grasses and herbs, including maidencane, spikerush, and beakrush	FNAI (1990)	50 to 100	

FNAI = Florida Natural Areas Inventory; m – meter; USNVC = United States National Vegetation Classification System.

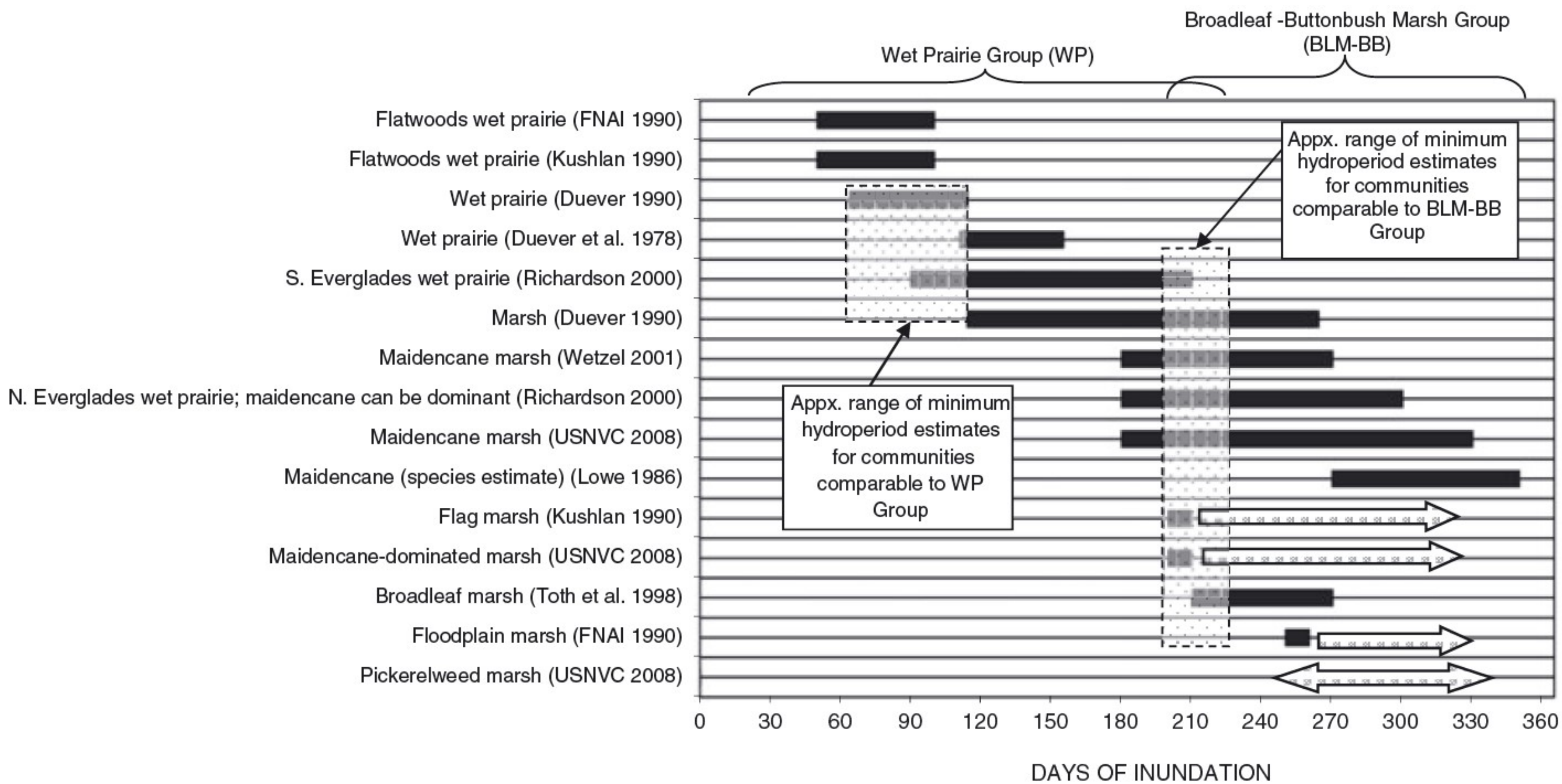

Figure F-1. Published estimates of Florida marsh plant community inundation durations.

*Gray arrows indicate estimates for which only a minimum inundation duration was described or no numerical estimate was provided (e.g., the duration given for pickerelweed marsh was "most of year with little variation in hydroperiod" in United States National Vegetation Classification System [USNVC 2008]). See **Table F-1** for additional details. Note: FNAI = Florida Natural Areas Inventory.*

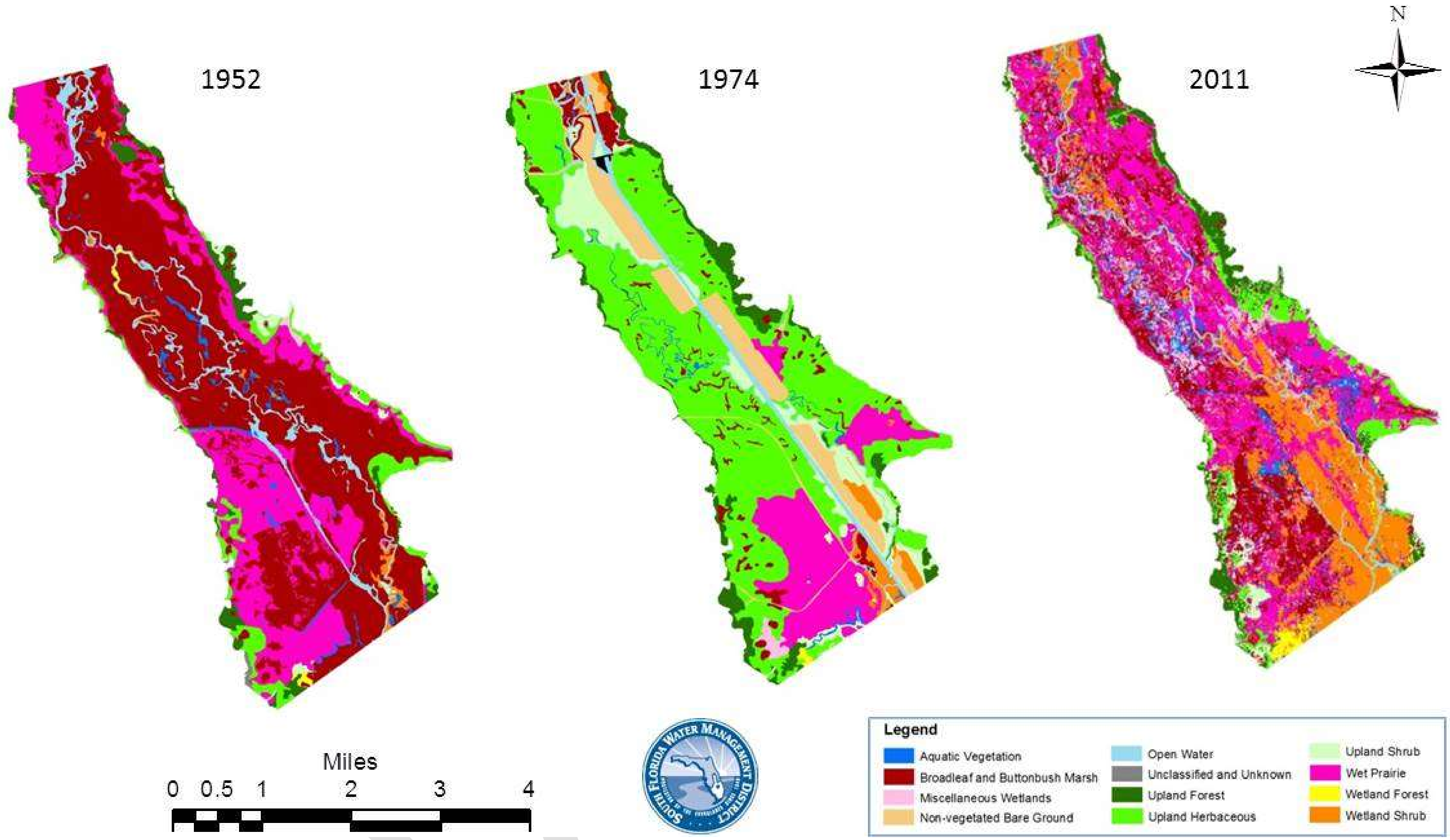

Figure F-2. Floodplain vegetation in the Phase I area of the Kissimmee River Restoration Project before channelization (left), 3 years after channelization was completed in 1971 (center), and 10 years after re-establishment of flow (right).

The Phase I construction area includes most of Pool C and portions of Pool B where flow and partial floodplain inundation were re-established in 2001. Red, pink, purple, and orange coloring denotes major wetland classes. Bright and light greens are upland classes. (Based on data from: Milleson et al. 1980, Pierce et al. 1982, Spencer and Bousquin 2014).

Wet Prairie Group

Communities included in the Wet Prairie group are variable in species composition. The group includes several herbaceous, emergent plant communities that have shorter hydroperiod requirements than the Broadleaf Marsh group. Almost all emergent marsh communities not classified as in the Broadleaf Marsh group are in the Wet Prairie group.

The Wet Prairie group comprises communities dominated by grasses and sedges, including maidencane, beakrushes (*Rhynchospora* spp.), soft rush (*Juncus effusus*), bushy broomgrass (*Andropogon glomeratus*), flatsedges (*Cyperus* spp.), spikerushes (*Eleocharis* spp.), Virginia iris (*Iris virginica*), cutgrass (*Leersia hexandra*), and watergrass (*Luziola fluitans*), as well as a few associations dominated by forbs, such as dotted smartweed (*Polygonum punctatum*). Additional details on the composition of Wet Prairie group community types can be found in the appendices to Bousquin and Carnal (2005).

The term "wet prairie" is used to classify a variety of emergent marsh communities occurring across a range of hydrologic situations (**Figure F-1**). The term often describes herbaceous graminoid-dominated communities in areas between longer hydroperiod wetlands and surrounding uplands, or in wet inclusions within uplands. Literature estimates of inundation duration for vegetation comparable in species composition to the Wet Prairie group range from 60 to 180 days per year (**Table F-1**, **Figure F-1**). The Wet Prairie group requires periodic drying (Goodrick and Milleson 1984, Barbour and Billings 2000) for germination and growth of seedlings. Wet Prairie group communities are believed to be adapted to fire and may depend on periodic burning to inhibit invasion by shrubs (Wade et al. 1980).

On the Kissimmee River floodplain, Wet Prairie group communities occur between the upper elevations of the Broadleaf Marsh group and surrounding uplands. Before channelization, Wet Prairie group communities occurred in an irregular, relatively narrow strip around much of the floodplain's periphery, and in depressions at higher elevations covering approximately 29% of the floodplain (**Figure F-2**) (Pierce et al. 1982, Spencer and Bousquin 2014). Following completion of the C-38 Canal in 1971, much of the Wet Prairie group distribution rapidly converted to various upland herbaceous communities and declined to 15% coverage (**Figure F-2**). Where these communities were used as pasture, shrub invasion was inhibited by grazing or mechanical maintenance; in less accessible places, large areas of upland shrub stands developed. By 1996, where conditions remained intermittently wet following channelization, the Wet Prairie and Wetland Shrub groups occupied areas that had been in the Broadleaf Marsh group, but at similar coverage (13%) as in 1971. Where backfilling was completed in 2001 for KRRP Phase I, a rapid conversion to wetland vegetation occurred by 2003, increasing Wet Prairie group coverage to 33%, with equivalent coverage (30%) being maintained to 2011 (**Figure F-2**). Much of this coverage is expected to convert to the Broadleaf Marsh group following completion of the project in 2020 following implementation of the Headwaters Revitalization Water Regulation Schedule (United States Army Corps of Engineers 1996) and re-establishment of longer floodplain hydroperiods.

Wetland Shrub Group

Several communities dominated by the following wetland-dependent shrub taxa fall into the Wetland Shrub group: buttonbush (*Cephalanthus occidentalis*), Carolina willow (*Salix caroliniana*), primrose willow (*Ludwigia peruviana* and/or *L. leptocarpa*), and St. John's wort (*Hypericum fasciculatum*). The last two species are not major components of the Kissimmee River floodplain.

Buttonbush is a native component of the Broadleaf Marsh group that comprises understories indistinguishable from the Broadleaf Marsh group but is classified as shrub stands due to areal cover of buttonbush that exceeds 30%. Therefore, hydrologic requirements of buttonbush communities are within the same range as the Broadleaf Marsh group. Carolina willow communities occur along abandoned channel oxbows and other slight rises in elevation on the floodplain, sometimes over large areas, and are an important source of cover and nesting substrate for wading birds (M. Cheek, SFWMD, personal observation) as in the southern Everglades (Frederick and Spalding 1994). Primrose willow, an exotic and invasive shrub, often occurs as an undesirable but persistent element of the Broadleaf Marsh group, particularly under the deep, stabilized water regimes that occur at water control structures in the lower regions of pools in the channelized condition. Primrose willow may brown and drop leaves when plants are flooded to approximately 50% to 70% of their height (B. Anderson and S. Bousquin, SFWMD, personal observation), but may rapidly re-sprout when water levels recede before death of the plants.

The Wetland Shrub group represented approximately 1% of the KRRP Phase I area floodplain vegetation prior to channelization of the Kissimmee River, remained low (3%) within 3 years of channelization (1974), and increased to 19% by the most recent complete vegetation map (2011, 10 years after completion of KRRP Phase I construction in 2001) (**Figure F-2**). Woody species respond more slowly than herbaceous vegetation; the 2011 increase likely began during the channelized period. Wetland Shrub group distributions may continue to be influenced by the current inability to fully re-establish pre-channelization hydroperiods. This situation is expected to be resolved by the revised water regulation schedule slated for implementation in 2020 (United States Army Corps of Engineers 1996).

FISH

Fish assemblages and hydrologic requirements are described in Chapter 4 of the main document. **Table F-2** provides a species list and life history characteristics.

Table F-2. Species of fish recorded from the Kissimmee River and their guild, spawning season, and mode of spawning.

Common Name	Scientific Name	Guild[1]	Spawning Season	Spawning Mode[2]
Bowfin	*Amia calva*	OS	April to July	N
Redfin pickerel	*Esox americanus*	OS	Spring and fall	SD
Chain pickerel	*Esox niger*	OS	Spring and fall	SD
Yellow bullhead	*Ameiurus natalis*	OS	April to May	N
Brown bullhead	*Ameiurus nebulosus*	OS	May	N
Tadpole madtom	*Noturus gyrinus*	OS	June to July	N
Pirate perch	*Aphredoderus sayanus*	OS	December to May	N/M
Flagfish	*Jordanella floridae*	OS	March to September	N, AVD
Bluefin killifish	*Lucania goodei*	OS	Spring to summer	SA
Mosquitofish	*Gambusia holbrooki*	OS	Late spring to summer	L
Least killifish	*Heterandria formosa*	OS	Most of the year	L
Sailfin molly	*Poecilia latipinna*	OS	Late spring/late summer	L
Everglades pygmy sunfish	*Elassoma evergladei*	OS		AVD
Okefenokee pygmy sunfish	*Elassoma okefenokee*	OS		AVD
Bluespotted sunfish	*Enneacanthus gloriosus*	OS	April to September	N
Longnose gar	*Lepisosteus osseus*	OD – R	March to September	SV
Florida gar	*Lepisosteus platyrhincus*	OD – R	April to October	SV
Gizzard shad	*Dorosoma cepedianum*	OD – R	April to June	SD
Threadfin shad	*Dorasoma petenense*	OD – L	May to July	SD

Common Name	Scientific Name	Guild[1]	Spawning Season	Spawning Mode[2]
Common carp – EXOTIC	*Cyprinus carpio*	OD – J	Spring	SF
Grass carp – EXOTIC	*Ctenopharyngodon idella*	OD – R	Spring	SA
Golden shiner	*Notemigonus crysoleucas*	OD – R	April to July	SD
Taillight shiner	*Notropis maculatus*	OD – L	March to August	SD
Coastal shiner	*Notropis petersoni*	OD – R, L, J	March to October	SD
Pugnose minnow	*Opsopoedus emiliae*	OD – J	March to September	SD
Lake chubsucker	*Erimyzon sucetta*	OD – J	May to July	SD
White catfish	*Ameiurus catus*	OD – J	April to July	N
Channel catfish	*Ictalurus punctatus*	OD – R	March to June	N
Walking catfish – EXOTIC	*Clarius batrachus*	OD – R	June to November	N
Brown hoplo – EXOTIC	*Hoplosternum littorale*	OD – R	June to November	NF
Seminole killifish	*Fundulus seminolis*	OD – R, L, J	April to summer	SA
Brook silverside	*Labidesthes sicculus*	OD – J	June to August	SA
Redbreast sunfish	*Lepomis auritrus*	OD – L	March to September	N
Warmouth	*Lepomis gulosus*	OD – R, L, J	April to October	N
Bluegill	*Lepomis machrochirus*	OD – R, L, J	February to October	N
Dollar sunfish	*Lepomis marginatus*	OD – R, L, J	April to September	N
Redear sunfish	*Lepomis microlophus*	OD – R, L, J	February to October	N
Spotted sunfish	*Lepomis punctatus*	OD – R, L, J	May to November	N
Largemouth bass	*Micropterus salmoides*	OD – R, L, J	December to May	N
Black crappie	*Pomoxis nigromaculatus*	OD – R, L, J	April to May	N
Oscar – EXOTIC	*Astronotus ocellatus*	OD – R, L, J		N
Blue tilapia – EXOTIC	*Oreochromis aureus*	OD – J		N/M
Golden topminnow	*Fundulus chrysostus*	OD – R	Late spring to summer	SA
Lined topminnow	*Fundulus lineotus*	HG		SA
Redface topminnow	*Fundulus rubifrons*	HG		SA
Tidewater silverside	*Menidia beryllina*	HG	June to August	SD
Swamp darter	*Etheostoma fusiforme*	HG	December to May	AVD
American eel	*Anguilla rostrata*	FS		SF
Atlantic needlefish	*Strongylura marina*	FS	Summer	AVD
Blackbanded darter	*Percina nigrofasciata*	FS		?
Stripped mullet	*Mugil cephalus*	FS		SD
Sailfin catfish – EXOTIC	*Pterygoplichthys disjunctivus*			N

[1] FS = fluvial specialist; HG = habitat generalist; J = juvenile; L = larval; OS = off channel specialist; OD = off channel dependent; R = reproduction. Habitat guild follows Glenn and Arrington (2005).

[2] AVD = demersal eggs attached to vegetation; L = livebearer; constructs floating nest; N = nest builder; N/M = nest builder/mouthbrooder; SA = scatters adhesive eggs; SD = scatters demersal eggs; SF = scatters floating eggs; SV = scatters eggs in vegetation. Spawning modes are from Trexler (1995).

AMPHIBIANS AND REPTILES

Amphibians and reptiles (herpetofauna) are abundant and often conspicuous inhabitants of freshwater broadleaf marshes. Amphibians are of particular ecological interest because of their complex life cycle, which includes an obligate association of larvae with water. As such, adult and larval amphibians, as well as reptiles, are particularly vulnerable to shifts in wetland hydrology (Pechmann et al. 1989).

Before 1960 and channelization of the Kissimmee River, the Broadleaf Marsh group was one of the dominant vegetation communities, covering approximately half of the floodplain within the KRRP area. Although detailed records of amphibian and reptile use of floodplain wetlands adjacent to the Kissimmee River are not available prior to channelization, Carr (1940) lists characteristic and frequently occurring amphibian and reptile taxa of Central Florida freshwater (broadleaf-like) marshes. These taxa likely accounted for most herpetofaunal species inhabiting floodplain marshes along the pre-channelized Kissimmee River.

Channelization of the river and conversion of wetlands to uplands, combined with shortened and unpredictable hydroperiods in remnant wetlands likely altered herpetofaunal communities (Koebel et al. 2005). Of the 24 species that likely occurred in pre-channelization Broadleaf Marsh group wetlands, only 3 were collected in the drained floodplain adjacent to the Kissimmee River (**Table F-3**): the green tree frog (*Hyla cinera*), the southern leopard frog (*Rana sphenocephala*), and the eastern cottonmouth (*Agkistrodon piscivorus*). The taxa that appear most affected are those that require long periods of inundation for reproduction (many anurans) and those that are entirely aquatic (salamanders). This reduction is a strong indicator that degraded Broadleaf Marsh group communities no longer adequately function to support the necessary refuge, foraging, and reproductive needs of amphibians and reptiles of the river-floodplain system.

Restoration of pre-channelization hydrology, including long-term floodplain inundation, is expected to re-establish historical floodplain wetland plant communities (Carnal 2005a,b) within the KRRP area. Hydrologic and wetland habitat restoration will be the impetus for recolonization of amphibians and reptiles characteristic of the pre-channelized Kissimmee River floodplain ecosystem. During extreme rainfall events, events that produce standing water on the unrestored Kissimmee River floodplain, all seven native anuran taxa and several species of reptiles likely to exist in natural wetlands of Central Florida were found in limited numbers on the floodplain (B. Anderson, SFWMD, unpublished data). Recruitment from remnant isolated wetlands and unaltered wetlands adjacent to and upstream of the restored river should contribute to rapid recolonization of the restored floodplain. For example, all 24 taxa likely to colonize restored wetlands (**Table F-3**) have been documented in wetlands of the Avon Park Air Force Range, adjacent to the floodplain (Franz et al. 2000). Other studies have shown that amphibians can colonize and reproduce in restored (Lehtinen and Galatowitsch 2001, Stevens et al. 2002, Petranka et al. 2003, Brodman et al. 2006) and constructed wetlands (Knutson et al. 2004).

Table F-3. Characteristic and frequently occurring aquatic amphibian and reptile taxa of Central Florida freshwater (broadleaf) marshes (From: Carr 1940).

Common Name	Scientific Name	Obligate Association with Water
Amphibians		
Amphiumidae		
Two-toed siren	*Amphiuma means*	A
Plethodontidae		
Dwarf salamander	*Eurycea quadridigitata*	A
Sirenidae		
Greater siren	*Siren lacertina*	A
Hylidae		
Florida chorus frog	*Pseudacris nigrita verrucosa*	L
Florida cricket frog	*Acris gryllus dorsalis*	L
Green tree frog*	*Hyla cinerea*	L
Little grass frog	*Pseudacris ocularis*	L
Squirrel tree frog	*Hyla squirella*	L
Ranidae		
Pig frog	*Rana grylio*	L
Southern leopard frog*	*Rana sphenocephala*	L
Reptiles		
Alligatoridae		
American alligator	*Alligator mississippiensis*	
Chelydridae		
Florida snapping turtle	*Chelydra serpentine osceola*	
Colobridae		
Eastern mud snake	*Farancia abacura*	
Florida green water snake	*Nerodia floridana*	
Florida water snake	*Nerodia fasciata pictiventris*	
South Florida swamp snake	*Seminatrix pygaea*	
Striped crayfish snake	*Regina alleni*	
Emydidae		
Florida chicken turtle	*Deirochelys reticularia*	
Peninsula red-bellied turtle	*Pseudemys nelsoni*	
Peninsular cooter	*Pseudemys floridana*	
Kinosternidae		
Common musk turtle	*Sternotherus odoratus*	
Florida mud turtle	*Kinosternon subrubrum steindachneri*	
Trionychidae		
Florida softshell turtle	*Trionyx ferox*	
Viperidae		
Eastern cottonmouth*	*Agkistrodon piscivorus*	

A = adult; L = larvae.
* Denotes taxa observed in degraded Broadleaf Marsh group (currently pasture) adjacent to the Kissimmee River.

BIRDS

Bird assemblages, hydrologic requirements, and life history characteristics are described in Chapter 4 of the main document and in **Tables F-4** and **F-5**.

Table F-4. Birds of the Kissimmee River floodplain, including seasonality and protective status.

Common Name	Scientific Name	Seasonality[1]	Status[2]
American bittern	*Botaurus lentiginosus*	V	
American coot	*Fulica americana*	R	
American crow	*Corvus brachyrhynchos*	R	
American redstart	*Setophaga ruticilla*	M	
American robin	*Turdus migratorius*	V	
American swallow-tailed kite	*Elanoides forficatus*	R	
American white pelican	*Pelecanus erythrorhynchos*	V	
American wigeon	*Anas americana*	V	
American woodcock	*Scolopax minor*	V	
Anhinga	*Anhinga anhinga*	R	
Bald eagle	*Haliaeetus leucocephalus*	R	
Baltimore oriole	*Icterus galbula*	V	
Barn owl	*Tyto alba*	R	
Barn swallow	*Hirundo rustica*	M	
Barred owl	*Strix varia*	R	
Belted kingfisher	*Megaceryle alcyon*	V	
Black skimmer	*Rynchops niger*	S	ST
Black tern	*Chlidonias niger*	M	
Black vulture	*Coragyps atratus*	R	
Black-bellied whistling duck	*Dendrocygna autumnalis*	R	
Black-crowned night heron	*Nycticorax nycticorax*	R	
Black-necked stilt	*Himantopus mexicanus*	R	
Blue-gray gnatcatcher	*Polioptila caerulea*	R	
Bluejay	*Cyanocitta cristata*	R	
Blue-winged teal	*Anas discors*	V	
Blue-winged warbler	*Vermivora pinus*	M	
Boat-tailed grackle	*Quiscalus major*	R	
Bobolink	*Dolichonyx oryzivorus*	M	
Bonapart's gull	*Chroicocephalus philadelphia*	S	
Brewer's blackbird	*Euphagus cyanocephalus*	S	
Brown pelican	*Pelecanus occidentalis*	S	
Brown thrasher	*Toxostoma rufum*	R	
Brown-headed cowbird	*Molothrus ater*	R	
Carolina wren	*Thryothorus ludovicianus*	R	
Caspian tern	*Hydroprogne caspia*	S	
Cattle egret	*Bubulcus ibis*	R	
Chimney swift	*Chaetura pelagica*	R	
Chuck-will's widow	*Caprimulgus carolinensis*	R	
Common grackle	*Quiscalus quiscula*	R	
Common ground dove	*Columbina passerina*	R	
Common moorhen	*Gallinula chloropus*	R	
Common nighthawk	*Chordeiles minor*	R	
Common yellowthroat	*Geothlypis trichas*	R	
Cooper's hawk	*Accipiter cooperii*	R	
Crested caracara	*Caracara cheriway*	R	FT
Double-crested cormorant	*Phalacrocorax auritus*	R	
Downy woodpecker	*Picoides pubescens*	R	
Eastern bluebird	*Sialia sialis*	R	
Eastern kingbird	*Tyrannus tyrannus*	R	
Eastern meadowlark	*Sturnella magna*	R	

Common Name	Scientific Name	Seasonality[1]	Status[2]
Eastern phoebe	*Sayornis phoebe*	V	
Eastern screech owl	*Megascops asio*	R	
Eastern towhee	*Pipilo erythrophthalmus*	R	
Eastern wood-peewee	*Contopus virens*	M	
Fish crow	*Corvus ossifragus*	R	
Florida burrowing owl	*Athene cunicularia floridana*	R	ST
Florida grasshopper sparrow	*Ammodramus savannarum floridanus*	R	FE
Florida sandhill crane	*Grus canadensis pratensis*	R	ST
Forster's tern	*Sterna forsteri*	V	
Fulvous whistling duck	*Dendrocygna bicolor*	R	
Glossy ibis	*Plegadis falcinellus*	R	
Golden-crowned kinglet	*Regulus satrapa*	S	
Gray catbird	*Dumetella carolinensis*	R	
Great blue heron	*Ardea herodias*	R	
Great egret	*Ardea alba*	R	
Great-crested flycatcher	*Myiarchus crinitus*	R	
Greater yellowlegs	*Tringa melanoleuca*	V	
Great horned owl	*Bubo virginianus*	R	
Green heron	*Butorides virescens*	R	
Green-winged teal	*Anas crecca*	V	
Gull-billed tern	*Gelochelidon nilotica*	S	
Hermit thrush	*Catharus guttatus*	V	
Herring gull	*Larus argentatus*	V	
Hooded merganser	*Lophodytes cucullatus*	V	
House wren	*Troglodytes aedon*	V	
Killdeer	*Charadrius vociferus*	R	
King rail	*Rallus elegans*	R	
Least bittern	*Ixobrychus exilis*	R	
Least sandpiper	*Calidris minutilla*	V	
Least tern	*Sternula antillarum*	S	ST
Lesser scaup	*Aythya affinis*	V	
Lesser yellowlegs	*Tringa flavipes*	V	
Limpkin	*Aramus guarauna*	R	
Lincoln's sparrow	*Melospiza lincolnii*	S	
Little blue heron	*Egretta caerulea*	R	ST
Loggerhead shrike	*Lanius ludovicianus*	R	
Long-billed dowitcher	*Limnodromus scolopaceus*	V	
Mallard	*Anas platyrhynchos*	R	
Marsh wren	*Cistothorus palustris*	V	
Merlin	*Falco columbarius*	V	
Mottled duck	*Anas fulvigula*	R	
Mourning dove	*Zenaida macroura*	R	
Northern bobwhite	*Colinus virginianus*	R	
Northern cardinal	*Cardinalis cardinalis*	R	
Northern flicker	*Colaptes auratus*	R	
Northern harrier	*Circus cyaneus*	V	
Northern mockingbird	*Mimus polyglottos*	R	
Northern parula	*Parula americana*	R	
Northern pintail	*Anas acuta*	V	
Northern rough-winged swallow	*Stelgidopteryx serripennis*	R	
Northern shoveler	*Anas clypeata*	V	
Northern waterthrush	*Seiurus noveboracensis*	M	
Osprey	*Pandion haliaetus*	R	
Ovenbird	*Seiurus aurocapilla*	V	
Painted bunting	*Passerina ciris*	V	
Palm warbler	*Dendroica palmarum*	V	
Peregrine falcon	*Falco peregrinus*	V	
Pied-billed grebe	*Podilymbus podiceps*	R	

Common Name	Scientific Name	Seasonality[1]	Status[2]
Pileated woodpecker	*Dryocopus pileatus*	R	
Pine warbler	*Dendroica pinus*	R	
Prairie warbler	*Dendroica discolor*	V	
Purple gallinule	*Porphyrio martinica*	R	
Purple martin	*Progne subis*	R	
Red-bellied woodpecker	*Melanerpes carolinus*	R	
Red-headed woodpecker	*Melanerpes erythrocephalus*	R	
Red-shouldered hawk	*Buteo lineatus*	R	
Red-tailed hawk	*Buteo jamaicensis*	R	
Red-winged blackbird	*Agelaius phoeniceus*	R	
Ring-necked duck	*Aythya collaris*	V	
Roseate spoonbill	*Platalea ajaja*	R	ST
Ruby-crowned kinglet	*Regulus calendula*	V	
Ruby-throated hummingbird	*Archilochus colubris*	R	
Ruddy duck	*Oxyura jamaicensis*	V	
Savannah sparrow	*Passerculus sandwichensis*	V	
Sedge wren	*Cistothorus platensis*	V	
Sharp-shinned hawk	*Accipiter striatus*	V	
Short-billed dowitcher	*Limnodromus griseus*	V	
Short-tailed hawk	*Buteo brachyurus*	R	
Snail kite	*Rostrhamus sociabilis*	R	FE
Snowy egret	*Egretta thula*	R	
Solitary sandpiper	*Tringa solitaria*	M	
Song sparrow	*Melospiza melodia*	V	
Sora	*Porzana carolina*	V	
Southeast American kestrel	*Falco sparverius paulus*	R, V	ST
Spotted sandpiper	*Actitis macularius*	V	
Summer tanager	*Piranga rubra*	R	
Swamp sparrow	*Melospiza georgiana*	V	
Tree swallow	*Tachycineta bicolor*	V	
Tricolored heron	*Egretta tricolor*	R	ST
Turkey vulture	*Cathartes aura*	R	
Vesper sparrow	*Pooecetes gramineus*	V	
Whip-poor-will	*Caprimulgus vociferus*	V	
White ibis	*Eudocimus albus*	R	
White-eyed vireo	*Vireo griseus*	R	
White-tailed kite	*Elanus leucurus*	S	
White-throated sparrow	*Zonotrichia albicollis*	V	
White-winged dove	*Zenaida asiatica*	R	
Wild turkey	*Meleagris gallopavo*	R	
Wilson's snipe	*Gallinago delicata*	V	
Wood duck	*Aix sponsa*	R	
Wood stork	*Mycteria americana*	R	FT
Yellow warbler	*Dendroica petechia*	M	
Yellow-bellied sapsucker	*Sphyrapicus varius*	V	
Yellow-billed cuckoo	*Coccyzus americanus*	R	
Yellow-breasted chat	*Icteria virens*	M	
Yellow-crowned night heron	*Nyctanassa violacea*	R	
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	S	
Yellow-rumped warbler	*Dendroica coronata*	V	
Yellow-throated warbler	*Dendroica dominica*	R	

[1] M = transient migrant (non-breeding); R = breeding resident; S = uncommon straggler (non-breeding); V = seasonal visitor (non-breeding).
[2] FT = threatened (federal), and FE = endangered (federal); ST = threatened (state). From: Florida Fish and Wildlife Conservation Commission. *Florida's Endangered and Threatened Species*. Updated December 2018.

Table F-5. Foraging and breeding habitat hydrologic requirements of wetland-obligate bird species of the Kissimmee River floodplain, including preferred foraging and breeding habitats.

Common Name	Scientific Name	Foraging Habitat Type	Foraging Hydrologic Requirements	Breeding Habitat Type	Breeding Hydrologic Requirements (Water Depth)
Ducks, Geese, and Swans (Anseriformes, Anatidae)					
American wigeon	*Anas americana*	All	0 to 20 cm	--	--
Black-bellied whistling duck	*Dendrocygna autumnalis*	All, OW	0 to ≤6.6 cm	WF (BLM, WS, WP)	Near water
Blue-winged teal	*Anas discors*	BLM, WP	13 to 88 cm (mean 30 cm)	--	--
Fulvous whistling-duck	*Dendrocygna bicolor*	All, OW	<0.5 m	BLM, WS, WP	<0.5 m
Green-winged teal	*Anas crecca*	All	0 to 25 cm (mean <12 cm)	--	--
Hooded merganser	*Lophodytes cucullatus*	All and OW	<1.5 m	--	--
Lesser scaup	*Aythya affinis*	OW, BLM	<3 m	--	--
Mallard	*Anas platyrhynchos*	All, OW	0-39 (mean 31 to 39 cm)	--	--
Mottled duck	*Anas fulvigula*	BLM, WP, WS, OW	<30 cm	WS, WP (obligatory nester near wetlands)	Within 15 to 219 m of water (mean 119 m)
Northern pintail	*Anas acuta*	BLM, WP, OW	0 to 30 cm	--	--
Northern shoveler	*Anas clypeata*	OW, BLM, WP	<40 cm	--	--
Ring-necked duck	*Aythya collaris*	All, OW	<1.5 m	--	--
Ruddy duck	*Oxyura jamaicensis*	OW, BLM, WP	1 to 3 m	--	--
Wood duck	*Aix sponsa*	WF, WS	18 to 40 cm (up to 1 m)	WF	Over or near water; <2 km from water maximum
Grebes (Podicipediformes, Podicipedidae)					
Pied-billed grebe	*Podilymbus podiceps*	All, OW	<6 m	BLM, WP, WS	>25 cm
Pelicans (Pelecaniformes, Pelecanidae)					
American white pelican	*Pelecanus erythrorhynchos*	BLM, WP	0.3 to 2.5 m	--	--
Brown pelican	*Pelecanus occidentalis*	BLM, WP, OW	Permanently flooded <150 m	--	--
Cormorants (Phalacrocoracidae)					
Double-crested cormorant	*Phalacrocorax auritus*	WS, WF, OW	<8 m	WF, WS	<10 km from water
Darters (Anhingidae)					
Anhinga	*Anhinga anhinga*	WS, WF, OW	<0.5 m	WF, WS	1 to 4.6 m above water

Common Name	Scientific Name	Foraging Habitat Type	Foraging Hydrologic Requirements	Breeding Habitat Type	Breeding Hydrologic Requirements (Water Depth)
Herons, Bitterns, and Allies (Ciconiiformes, Ardeidae)					
American bittern	*Botaurus lentiginosus*	BLM, WP	Mean 10 cm	--	--
Black-crowned night heron	*Nycticorax nycticorax*	All, OW	<20 cm	WF, WS	Over water >0.5 m March to August; recession <18.3 cm/week
Great blue heron	*Ardea herodias*	All, OW	<40 cm	WF, WS	Over water >0.5 m March to August; recession <18.3 cm/week
Great egret	*Ardea alba*	All, OW	<28 cm	WF, WS	Over water >0.5 m March to August; recession <18.3 cm/week
Green heron	*Butorides virescens*	All, OW	<10 cm	WF, WS	Over water >0.5 m March to August; recession <18.3 cm/week
Least bittern	*Ixobrychus exilis*	BLM, WS, WP	1 to 60 cm; usually at surface	BLM, WS, WP	Over water >0.5 m March to August; recession <18.3 cm/week
Little blue heron	*Egretta caerulea*	All, OW	<17 cm	WF, WS	Over water >0.5 m March to August; recession <18.3 cm/week
Snowy egret	*Egretta thula*	All, OW	<17 cm	WF, WS	Over water >0.5 m March to August; recession <18.3 cm/week
Tricolored heron	*Egretta tricolor*	All, OW	<18 cm	WF, WS	Over water >0.5 m March to August; recession <18.3 cm/week
Yellow-crowned night heron	*Nyctanassa violacea*	All, OW	<10 cm	WF, WS	Over water >0.5 m March to August; recession <18.3 cm/week
Ibises and Spoonbills (Threskiornithidae)					
Glossy ibis	*Plegadis falcinellus*	All, OW	<10 cm	All	Over water >0.5 m March to August; recession <18.3 cm/week
Roseate spoonbill	*Platalea ajaja*	All, OW	<20 cm (mean ≤12 cm)	WF, WS	Over water >0.5 m March to August; recession <18.3 cm/week
White ibis	*Eudocimus albus*	All, OW	<20 cm (mean 5 to 10 cm)	WF, WS (BLM, WP)	Over water >0.5 m March to August; recession <18.3 cm/week
Storks (Ciconiidae)					
Wood stork	*Mycteria americana*	All, OW	<50 cm	WF, WS	Over water >0.5 m March to August; recession <18.3 cm/week
Hawks, Kites, Eagles, and Allies (Falconiformes, Accipitridae)					
Bald eagle	*Haliaeetus leucocephalus*	BLM, WP, OW	0 to 2 m	WF (<2 km water)	<2 km from open water
Osprey	*Pandion haliaetus*	All, OW	0.5 to 2 m	WF (obligatory nester near water)	<1 to 20 km from open water
Snail kite	*Rostrhamus sociabilis*	BLM, WP, WS, OW	0.2 to 1.3 m	WS, WF	36 to 93 cm

Common Name	Scientific Name	Foraging Habitat Type	Foraging Hydrologic Requirements	Breeding Habitat Type	Breeding Hydrologic Requirements (Water Depth)
Rails, Gallinules, and Coots (Gruiformes, Rallidae)					
American coot	*Fulica americana*	All, OW	<6 m	All	Over permanent water <1.2 m from open water
Common moorhen	*Gallinula chloropus*	All, OW	15 to 120 cm	WS, BLM, WP	0 to 60 cm
King rail	*Rallus elegans*	BLM, WS, WP	<10 cm	BLM, WS, WP	10 to 46 cm
Purple gallinule	*Porphyrio martinica*	All, OW	0.25 to 1 m	BLM, WF, WS	14.7 cm (6 to 26 cm)
Sora	*Porzana carolina*	BLM, WP, WS	<15 cm (0 to 46 cm)	--	--
Limpkins (Aramidae)					
Limpkin	*Aramus guarauna*	BLM, WS, WF, OW	<30 cm	All	61.2 cm (41 to 122 cm)
Cranes (Gruidae)					
Florida sandhill crane	*Grus canadensis pratensis*	BLM, WEP	0 to 30 cm	BLM, WEP, WS	13.5 to 32.6 cm
Stilts and Avocets (Charadriiformes, Recurvirostridae)					
Black-necked stilt	*Himantopus mexicanus*	BLM, WS, WP, OW	<13 cm	BLM, WP	Usually over water or <50 m from open water
Sandpipers and Allies (Scolopacidae)					
Greater yellowlegs	*Tringa melanoleuca*	BLM, WP, OW	5 to 7.4 cm	--	--
Least sandpiper	*Calidris minutilla*	BLM, WP, WS, OW	<4 cm	--	--
Lesser yellowlegs	*Tringa flavipes*	BLM, WP, WS, OW	2.6 cm (4 to 16 cm)	--	--
Long-billed dowitcher	*Limnodromus scolopaceus*	BLM, WS, WP, OW	0 to 16 cm	--	--
Short-billed dowitcher	*Limnodromus griseus*	BLM, WS, WP, OW	<8 cm	--	--
Solitary sandpiper	*Tringa solitaria*	BLM, WP, WS, OW	<5 cm	--	--
Spotted sandpiper	*Actitis macularius*	BLM, WP, OW	<4 cm	--	--
Wilson's snipe	*Gallinago delicata*	All	<8 cm	--	--
Skuas, Gulls, Terns, and Skimmers (Laridae)					
Black skimmer	*Rynchops niger*	BLM, WP, OW	<2.5 to 20 cm	--	--
Black tern	*Chlidonias niger*	BLM, WP, OW	>0.5 m	--	--
Bonapart's gull	*Chroicocephalus philadelphia*	BLM, WP, OW	>0.5 m	--	--
Caspian tern	*Hydroprogne caspia*	BLM, WP, OW	0.5 to 5 m	--	--
Forster's tern	*Sterna forsteri*	OW, BLM, WP	<1 m	--	--
Gull-billed tern	*Gelochelidon nilotica*	BLM, WP, OW	0 to 5 m	--	--
Herring gull	*Larus argentatus*	WP, BLM, OW	<1-2 m	--	--
Least tern	*Sternula antillarum*	BLM, WP, WS, OW	0 to 5 m	--	--

Common Name	Scientific Name	Foraging Habitat Type	Foraging Hydrologic Requirements	Breeding Habitat Type	Breeding Hydrologic Requirements (Water Depth)
Kingfishers (Coraciiformes, Alcedinidae)					
Belted kingfisher	*Megaceryle alcyon*	All, OW	<60 cm	--	--
Swallows (Passeriformes, Hirundinidae)					
Tree swallow	*Tachycineta bicolor*	All	Any	--	--
Wrens (Troglodytidae)					
Marsh wren	*Cistothorus palustris*	WS, WF, WP, BLM	<1 m	--	--
Emberezids (Emberizidae)					
Swamp sparrow	*Melospiza georgiana*	All	<4 cm	--	--
Blackbirds (Icteridae)					
Boat-tailed grackle	*Quiscalus major*	All, OW	<8 cm	WF, WS (BLM, WP) (obligatory nester near water)	93.1 cm
Red-winged blackbird	*Agelaius phoeniceus*	All	<1 m	WS, BLM, WP	<1 m

All = all habitats, except open water; BLM = Broadleaf Marsh; OW = Open Water; WF = Wet Forest; WP = Wet Prairie; WS = Wet Shrub.
-- Breeding range occurs outside of the Kissimmee River floodplain.
Foraging and breeding habitat information and hydrologic requirements were obtained from point count surveys along the river and from Willard (1977), Powell (1987), Stys (1997), Guillemain et al. (2000), Poole (2008), and Florida Fish and Wildlife Conservation Commission (2003).

MAMMALS

Currently, 26 species of mammals use the Kissimmee River and floodplain, including 4 resident breeders and 2 federally listed species, the Florida panther (*Puma concolor coryi*) and the Florida bonneted bat (*Eumops floridanus*) (**Table F-6**). Although mammals are not monitored as part of the Kissimmee River Restoration Evaluation Program, populations likely were negatively impacted by losses of wetland habitat and alteration of hydrology caused by channelization.

Mammals using the Kissimmee River and floodplain include 4 obligate wetland species (**Table F-7**), 18 facultative breeders, and 4 opportunistic foragers. Brief summaries of the aquatic life history requirements of several species of mammals are described below. Foraging and breeding habitat hydrologic requirements of wetland-dependent species are summarized in **Table F-7**.

The marsh rabbit (*Sylvilagus palustris*), marsh rice rat (*Oryzomys palustris*), and round-tailed muskrat (*Neofiber alleni*) depend on dense emergent aquatic vegetation for cover and to construct their houses and/or nests near water (Birkenholz 1972, Chapman and Willner 1981, Wolfe 1982). The largely vegetarian diet of all three species comprises the roots, stems, leaves, and seeds of herbaceous wetland plants occurring in Broadleaf Marsh and Wet Prairie group habitats.

River otters (*Lontra canadensis*) nest in hollow trees or logs, undercut riverbanks, backwater sloughs, flood debris, or burrows excavated by other animals, such as the gray fox (*Uroncyon cinereoargenteus*) (Lariviere and Walton 1998). They depend entirely on aquatic habitats for their main prey, including fish, amphibians, crayfish (*Procambarus* spp.), and other aquatic invertebrates.

The 22 facultative and opportunistic wetland mammals include 2 federally endangered species, the Florida panther and the Florida bonneted bat (Florida Fish and Wildlife Conservation Commission 2018). The Florida panther has been documented on several occasions within the 100-year floodline. The Florida bonneted bat was observed foraging over the Kissimmee River floodplain in Pool A, well outside of its reported range south and west of Lake Okeechobee (Belwood 1992, Marks and Marks 2008). However, these species are considered opportunistic users of the Kissimmee River floodplain.

Table F-6. Mammals of the Kissimmee River and floodplain.

Common Name	Scientific Name
Armadillo	*Dasypus novemcinctus*
Bobcat	*Lynx rufus*
Brazilian freetailed bat	*Tadarida b. cynocephala*
Coyote	*Canis latrans*
Eastern cottontail	*Sylvilagus floridanus*
Eastern gray squirrel	*Sciurus carolinensis*
Eastern mole	*Scalopus aquaticus*
Eastern pipistrel bat	*Pipistrellus subflavus*
Eastern woodrat	*Neotoma floridana*
Evening bat	*Nycticeius humeralis*
Feral hog	*Sus scrofa*
Florida black bear	*Ursus americanus floridanus*
Florida bonneted bat*	*Eumops floridanus*
Florida panther*	*Puma concolor coryi*
Gray fox	*Uroncyon cinereoargenteus*
Marsh rabbit	*Sylvilagus palustris*
Marsh rice rat	*Oryzomys palustris*
Northern yellow bat	*Lasiurus i. floridanus*
Opossum	*Didelphis marsupialis*
Raccoon	*Procyon lotor*
River otter	*Lontra Canadensis*
Round-tailed muskrat	*Neofiber alleni*
Seminole bat	*Lasiurus seminolus*
Sherman's fox squirrel	*Sciurus niger shermani*
Striped skunk	*Mephitis mephitis*
Whitetail deer	*Odocoileus virginianus*

* Endangered (federal).

Table F-7. Status and hydrologic requirements of foraging and breeding wetland-obligate mammals of the Kissimmee River.

Common Name	Scientific Name	Status	Foraging Habitat Type	Foraging Hydrologic Requirements	Breeding Habitat Type	Breeding Hydrologic Requirements
Carnivora, Mustelidae						
River otter	*Lutra canadensis*	R	All, OW	0-10 m near permanent water	All (burrows, hollows)	Adjacent to permanent water
Rodentia, Cricetidae						
Marsh rice rat	*Oryzomys palustris*	R	BLM, WP, WS	<1 m	BLM, WP, WS	>30 cm above high water
Round-tailed muskrat	*Neofiber alleni*	R	BLM, WP, WS	15-46 cm	BLM, WP, WS	15-46 cm
Lagomorpha, Leporidae						
Marsh rabbit	*Sylvilagus palustris*	R	All	<1 m	All	Adjacent to water

BLM = Broadleaf Marsh; OW = Open Water; R = breeding resident; WP = Wet Prairie; WS = Wet Shrub.
Foraging and breeding habitat hydrologic requirements obtained from Birkenholz (1972), Chapman and Willner (1981), Wolfe (1982), and Lariviere and Walton (1998).

LITERATURE CITED

Barbour, M.G. and W.D. Billings. 2000. *North American Terrestrial Vegetation*, Second Edition. Cambridge University Press, Cambridge, United Kingdom and New York, NY.

Belwood, J. 1992. *Florida Mastiff Bat,* Eumops glaucinus floridanus, pp. 216-223. In: S.R. Humphrey (ed.), Rare and Endangered Biota of Florida, Volume I, Mammals. University Press of Florida, Gainesville, FL.

Birkenholz, D.E. 1972. *Neofiber alleni*. The American Society of Mammalogists 15:4.

Bousquin, S.G. and L.L. Carnal. 2005. *Chapter 9: Classification of the Vegetation of the Kissimmee River and Floodplain*. In: S.G. Bousquin, D.H. Anderson, G.E. Williams, and D.J. Colangelo (eds.), Kissimmee River Restoration Studies, Volume I, Establishing a Baseline: Pre-Restoration Studies of the Channelized Kissimmee River. Technical Publication ERA 432. South Florida Water Management District, West Palm Beach, FL.

Bousquin, S.G., D.H. Anderson, D.J. Colangelo, and G.E. Williams. 2005. *Introduction to Baseline Studies of the Channelized Kissimmee River*. In: S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo (eds.), Kissimmee River Restoration Studies, Volume I, Establishing a Baseline: Pre-Restoration Studies of the Channelized Kissimmee River. Technical Publication ERA 432. South Florida Water Management District, West Palm Beach, FL.

Brodman, R., M. Parrish, H. Kraus, and S. Cortwright. 2006. *Amphibian biodiversity recovery in a large-scale ecosystem restoration*. Herpetological Conservation and Biology 1:101-108.

Carnal, L.L. 2005a. *Expectation 12: Areal Coverage of Floodplain Wetlands*. In D.H. Anderson, S.G. Bousquin, G.E. Williams, and D.J. Colangelo (eds.), Kissimmee River Restoration Studies, Volume II, Defining Success: Expectations for the Kissimmee River Restoration. Technical Publication ERA 433. South Florida Water Management District, West Palm Beach, FL.

Carnal, L.L. 2005b. *Expectation 13: Areal Coverage of Broadleaf Marsh*. In: D.H. Anderson, S.G. Bousquin, G.E. Williams, and D.J. Colangelo (eds.), Kissimmee River Restoration Studies, Volume II, Defining Success: Expectations for the Kissimmee River Restoration. Technical Publication ERA 433. South Florida Water Management District, West Palm Beach, FL.

Carnal, L.L. and S.G. Bousquin. 2005. *Chapter 10: Areal Coverage of Floodplain Plant Communities in Pool C of the channelized Kissimmee River*. In: S.G. Bousquin, D.H. Anderson, G.E. Williams, and D.J. Colangelo (eds.), Kissimmee River Restoration Studies, Volume I, Establishing a Baseline: Pre-Restoration Studies of the Channelized Kissimmee River. Technical Publication ERA 432. South Florida Water Management District, West Palm Beach, FL.

Carr, A.F. 1940. *A Contribution to the Herpetology of Florida*. Biological Science Series 3(1). University of Florida, Gainesville, FL.

Chapman, J.A. and G.R. Willner. 1981. *Sylvilagus palustris*. The American Society of Mammalogists 153:3.

Davis, J.H. 1943. *The Natural Features of Southern Florida, Especially the Vegetation, and the Everglades*. Geological Bulletin Number 25. Florida Geological Survey, State of Florida Department of Conservation, Tallahassee, FL.

Duever, M.J. 1990. *The long-term variability of restored wetlands*, pp. 279-289. In: M.K. Loftin, L.A. Toth, and J.T.B. Obeysekera (eds.), Proceedings Kissimmee River Restoration Symposium. South Florida Water Management District, West Palm Beach, FL.

Duever, M.J., J.E. Carlson, L.A. Riopelle, and L.C. Duever. 1978. *Ecosystem Analyses at Corkscrew Swamp*, pp. 534-565. In: H.T. Odum and K.C. Ewel (eds.), Cypress Wetlands for Water Management, Recycling and Conservation. Fourth annual report to National Science Foundation Program of Research Applied to National Needs and the Rockefeller Foundation, Center for Wetlands, University of Florida, Gainesville, FL.

Florida Fish and Wildlife Conservation Commission. 2003. *Florida's Breeding Bird Atlas: A Collaborative Study of Florida's Birdlife*. Florida Fish and Wildlife Conservation Commission.

Florida Fish and Wildlife Conservation Commission. 2018. *Florida's Endangered Species, Threatened Species and Species of Special Concern*. Florida Fish and Wildlife Conservation Commission.

Florida Natural Areas Inventory. 1990. *Guide to the Natural Communities of Florida*. Florida Natural Areas Inventory, Florida Department of Natural Resources, Tallahassee, FL.

Franz, R., D. Maehr, A. Kinlaw, C. O'Brien, and R.D. Owen. 2000. *Amphibians and Reptiles of the Bombing Range Ridge, Avon Park Air Force Range, Highlands and Polk Counties, Florida*. Florida Museum of Natural History, Gainesville, FL.

Frederick, P.C. and M.G. Spalding. 1994. *Factors affecting reproductive success of wading birds (Ciconiiformes) in the Everglades ecosystem*, pp. 659-691. In: S. Davis and J.C. Ogden (eds.), Everglades: The Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL.

Gladden, J.E. and L.A. Smock. 1990. *Macroinvertebrate distribution and production on the floodplains of two lowland headwater streams*. Freshwater Biology 24:533-545.

Glenn, J.L., III and D.A. Arrington. 2005. *Chapter 13. Status of Fish Assemblages of the Kissimmee River Prior to Restoration: Baseline Conditions and Expectations for Restoration*. In: S.G. Bousquin, D.H. Anderson, G.E. Williams, and D.J. Colangelo (eds.), Kissimmee River Restoration Studies, Volume I, Establishing a Baseline: Pre-Restoration Studies of the Channelized Kissimmee River. Technical Publication ERA 432. South Florida Water Management District, West Palm Beach, FL.

Goodrick, R.L. and J.F. Milleson. 1984. *Studies of the Floodplain Vegetation and Water Level Fluctuation in the Kissimmee River Valley*. Technical Publication 74-2 (DRE-40). South Florida Water Management District, West Palm Beach, FL.

Guillemain, M., H. Fritz, and N. Guillon. 2000. *Foraging behavior and habitat choice of wintering northern shoveler in a major wintering quarter in France*. Waterbirds 23(3):353-363.

Knutson, M.G., W.B. Richardson, D.M. Reineke, B.R. Gray, J.R. Parmelee, and S.E. Weick. 2004. *Agricultural ponds support amphibian populations*. Ecological Applications 14(3):669-684.

Koebel, J.W., Jr., J.L. Glenn III, and R.H. Carroll IV. 2005. *Chapter 12: Amphibian and Reptile Communities of the Lower Kissimmee River Basin Prior to Restoration: Baseline and Reference Conditions and Expectations for Restoration*. In: S.G. Bousquin, D.H. Anderson, G.E. Williams, and D.J. Colangelo (eds.), Kissimmee River Restoration Studies, Volume I, Establishing a Baseline: Pre-Restoration Studies of the Channelized Kissimmee River. Technical Publication ERA 432. South Florida Water Management District, West Palm Beach, FL.

Kushlan, J.A. 1990. *Freshwater Marshes*, pp. 324-263. In: R.L. Myers and J.J. Ewel (eds.), Ecosystems of Florida. University of Central Florida Press, Orlando, FL.

Lariviere, S. and L. Walton. 1998. *Lontra canadensis*. Mammalian Species No. 587:8. The American Society of Mammalogists.

Lehtinen, R. and S.M. Galatowitsch. 2001. *Colonization of restored wetlands by amphibians in Minnesota*. American Midland Naturalist 145:388-396.

Lowe, E.F. 1986. *The relationship between hydrology and vegetational pattern within the floodplain marsh of a subtropical, Florida lake*. Florida Scientist 49:213-233.

Marks, C. and G. Marks. 2008. *Bat Conservation and Land Management: Kissimmee River Wildlife Management Area*. The Florida Bat Conservancy, Bay Pines, FL.

Milleson, J.F., R.L. Goodrick, and J.A. Van Arman. 1980. *Plant Communities of the Kissimmee River Valley*. Technical Publication 80-7. South Florida Water Management District, West Palm Beach, FL.

Pechmann, J.H.K., D.E. Scott, J.W. Gibbons, and R.D. Semlitsch. 1989. *Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians*. Wetlands Ecology and Management 1:3-11.

Petranka, J.W., S.S. Murray, and C.A. Kennedy. 2003. *Responses of amphibians to restoration of a southern Appalachian wetland: perturbations confound post-restoration assessment*. Wetlands 23:278-290.

Pierce, G.J., A.B. Amerson, and L.R. Becker. 1982. *Final Report: Pre-1960 Floodplain Vegetation of the Lower Kissimmee River Valley, Florida*. Biological Services Report 82-3, United States Army Corps of Engineers, Jacksonville, FL.

Poole, A. (ed.). 2008. *The Birds of North America Online*. Cornell Lab of Ornithology, Ithaca, NY. Available online at http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna.

Powell, G. 1987. *Habitat use by wading birds in a subtropical estuary: Implications of hydrography*. The Auk 104:740-749.

Richardson, C.J. 2000. *Chapter 12: Freshwater Wetlands*, pp. 488-499. In: M.G. Barbour and W.D. Billings (eds.), North American Terrestrial Vegetation, Second Edition. Cambridge University Press, Cambridge, UK.

Scheaffer, W.A. and J.G. Nickum. 1986. *Backwater areas as nursery habitats for fishes in Pool 13 of the Upper Mississippi River*. Hydrobiologia 136:131-140.

Schomer, N.S. and R.D. Drew. 1982. *An Ecological Characterization of the Lower Everglades, Florida Bay, and the Florida Keys*. FWS/OBS-82/58, United States Fish and Wildlife Service for the United States Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Office, Metairie, LA. NTIS Number PB83-141978.

Spencer, L. and S. Bousquin. 2014. *Interim responses of floodplain wetland vegetation to Phase I of the Kissimmee River Restoration Project: Comparisons of vegetation maps from five periods in the river's history*. Restoration Ecology 22(3):397-408.

Stevens, C.E., A.W. Diamond, and T.S. Gabor. 2002. *Anuran call surveys on small wetlands in Prince Edward Island, Canada Restored by dredging of sediments*. Wetlands 22(1):90-99.

Stys, B. 1997. *Ecology of the Florida Sandhill Crane*. Nongame Wildlife Technical Report Number 15. Florida Game and Freshwater Fish Commission, Tallahassee, FL.

Toth, L.A. 1991. *Environmental Responses to the Kissimmee River Demonstration Project*. Technical Publication 91-02. South Florida Water Management District, West Palm Beach, FL.

Toth, L.A. 1993. *The ecological basis of the Kissimmee River Restoration Plan*. Florida Scientist 56:25-51.

Toth, L.A., D.A. Arrington, M.A. Brady, and D.A. Muszick. 1995. *Conceptual evaluation of factors potentially affecting restoration of habitat structure within the channelized Kissimmee River ecosystem*. Restoration Ecology 3:160-180.

Toth, L.A., S.L. Melvin, D.A. Arrington, and J. Chamberlain. 1998. *Hydrologic manipulations of the channelized Kissimmee River*. Bioscience 48:757-764.

Trexler, J.C. 1995. Restoration of the Kissimmee River: a conceptual model of past and present fish communities and its consequences for evaluating restoration success. Restoration Ecology 3:195-210.

United States Army Corps of Engineers. 1996. *Central and Southern Florida Project Kissimmee River Headwaters Revitalization Project Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement*. United States Army Corps of Engineers, Jacksonville, FL. January 1996.

United States National Vegetation Classification System. 2008. *International Ecological Classification Standard: Terrestrial Ecological Classifications, International Vegetation Classification*. NatureServe Central Databases, Arlington, VA. Searchable online database of United States National Vegetation Classification System and International Vegetation Classification Community Types and Association Descriptions. Available online at http://www.natureserve.org/explorer/servlet/NatureServe.

Wade, D.D., J.J. Ewel, and R.H. Hofstetter. 1980. *Fire in South Florida Ecosystems*. Forest Service General Technical Report SE-17. Southeastern Forest Experiment Station, Ashville, NC.

Wetzel, P.R. 2001. *Plant Community Parameter Estimates and Documentation for the Across Trophic Level System Simulation (ATLSS)*. Data report prepared for the ATLSS Project Team, The Institute of Environmental Modeling, University of Tennessee–Knoxville, Knoxville, TN.

Willard, D.E. 1977. *The feeding ecology and behavior of five species of herons in southeastern New Jersey*. The Condor 79:462-470.

Wolfe, J.L. 1982. *Oryzomys palustris*. Mammalian Species Number 176:5. The American Society of Mammalogists.